Project

Two storeyed office building of West Bengal Renewable Energy Development Agency

Site

Plot JI-10, Sector V, Salt Lake City Electronics Complex, Calcutta

Architect and consultant

Gherzi Eastern Limited
43 Fazlul Haque Sarani
Calcutta - 700 019

Coordinator. S P. Pramanik

Energy consultant

Tata Energy Research Institute
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi - 110 003

Coordinator: Anil Misra

Sponsors

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- West Bengal Renewable Energy Development Agency

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Preface

Modern architectural practices and the concepts of energy conservation in buildings and their environment friendliness are expected to affect large energy savings by way of appropriate design interventions. The achievement can be made with the highlight on climatically responsive energy efficient architecture.

It has been observed that the energy produced in the country is consumed to the extent of about 50% towards the maintenance and construction of our buildings. This is the result of the use of conventional materials and equipments and the present building construction techniques More clearly, it can be stated that 17% of total commercial energy in the country is utilized for building services like lighting, air conditioning, ventilation, and other building appliances.

A more appropriate approach to building design requires tremendous control in the study and diagnosis through the environmental system comprising climatic phases of different zones, thermal properties of materials and surroundings, usage of landscaping/green scenario and optimum design for these factors to achieve the desired human comfort and services in buildings.

An effort, based on these concepts has been made to evolve an energy conscious design for the office building of the West Bengal Renewable Energy Development Agency (WBREDA). Special attention has been paid to the building external envelope and the systems, namely the air-conditioning and lighting system. The use of day light has been optimized with respect to the thermal performance of the building The analysis of the design shows that the proposed design is much more energy-efficient than a conventional design of an office building. This will bring up low energy architecture concept in function with a greater value for the purpose of conservation of energy

The detailed project report (DPR) on the proposed design of WBREDA office building prepared jointly by TERI and GEL, highlights the correct design approach, which moves from the global considerations (climate, site) to the specific context of passive systems.

Acknowledgements

On behalf of GEL & TERI we express our gratitude to Dr.S.K.Sen, Minister in Charge of Power, Science & Technology & Non Conventional Energy sources Govt. of West Bengal for his patronage & encouragement for this Project.

GEL and TERI place on record their sincere thanks to the West Bengal Renewable Energy Development Agency (WBREDA) for entrusting with the assignment of designing the energy efficient office building of WBREDA at Calcutta.

The coordinators are thankful to the India Meteorological Department for providing us the hourly weather data of the year 1994 for Calcutta.

We are thankful to our colleagues at GEL and TERI who helped us in completing the assignment and in the finalization of this report.

Our thanks to Mr. Mohasin Sheikh of GEL and Ms Ritu Luthra of TERI for the preparation of this document.

S.P. Pramanik
Anil Misra

1. Introduction

1.1 Background of the project

West Bengal Renewable Energy Development Agency (WBREDA) is an organization of the Department of Science and Technology, Government of West Bengal, having its present office at B-04, Block LA, Sector III, Salt Lake City, Calcutta. WBREDA is a nodal agency of the Ministry of Non-conventional Energy Sources (MNES), Government of India and works to promote, disseminate and popularize the use of new and renewable energy technologies in the region of West Bengal.

West Bengal Electronics Development Corporation has allotted a plot of land of about 11700 sq ft at Salt Lake City Electronics Complex, Block ED, Sector V, Plot JI-10 for the construction of permanent office building of WBREDA.

WBREDA have engaged M/s Gherzi Eastern Ltd, having its Head Office at Neville House, J.N. Heredia Marg, Ballard Estate, Bombay - 400 038 and Eastern Regional Office at 43, Fazlul Haque Sarani, Calcutta - 700 019, as Architect and Consultant for the project. M/s Gherzi Eastern Ltd, has tied up with Tata Energy Research Institute (TERI), Darbari Seth Block, Habitat Place, Lodhi Road, New Delhi for thermal optimization of the office building design by incorporating the concepts of solar passive architecture, daylight integration and energy efficient lighting design.

1.2 About WBREDA

West Bengal Renewable Energy Development Agency (WBREDA) was set up by the State Government to promote and popularise renewable energy programme in the State of West Bengal with special emphasis for rural areas. It has already done a good deal of pioneering work not only in popularising the alternative energy technologies but also in adopting and evolving technologies to suit the particular conditions obtaining in this part of the world.

The West Bengal Renewable Energy Development Agency has started functioning from the year 1993 and since then, the State has witnessed an organised and systematic renewable energy programmes. The activities of WBREDA may be divided in the following categories :-

(A) Implementation programmes related to non-conventional energy sources like solar photovoltaic, solar Thermal, Wind Energy, Biomass, Mini & Micro Tydel Power, Tidal power,etc.

(B) Publication of various informations and documentations of non-conventional energy programmes being implemented in the State of West Bengal.

(C) Promotion, development, demonstration, dessimination and popularisation of new and renewable energy technologies for harnessing energy from the Sun, Wind, Water, Biomass, Ocean, etc.

(D) Implementation of national level scheme of MNES in the State of West Bengal.

The West Bengal Renewable Energy Development Agency is headed by the Minister In-Charge of Power, Science & Technology and Non-conventional Energy Sources, Govt. of West Bengal. The Minister is assisted by a group of technologists, administrators.

SOLAR ENERGY PROGRAMME :

The Sun is indirectly responsible for most of our existing energy production. Solar energy can be harnessed in two ways :-

i) Solar Thermal route
ii) Solar Photovoltaic route

i) In West Bengal a large number of Solar Thermal Devices are in operation. This include Solar Water Heaters, Solar Cookers, Solar Distillation Plants, etc. West Bengal bagged the best performance Award of MNES for solar Thermal programme in the year 1993-94.

ii) Solar photovoltaic is another important route where electricity is generated from sunlight directly. Solar Lantern, Domestic Solar Lighting System, Solar Street Light and Solar Power Plant are now-a-days not dream but reality. A large number of Solar PV systems are working in the areas like Bangopalpur, Bankura District, Sagar Island, South 24 Parganas District, Gosaba, South 24 Parganas District, Hingalganj, North 24 Parganas District and a vast part of Midnapore District in the coastal areas Thousands of families are getting benefits from the solar lighting devices A large number of jobs has also been generated from this programme.

WIND ENERGY PROGRAMME :

WBREDA is implementing wind energy programme in the State of West Bengal. In order to harness wind energy, first of all collection of wind data in different locations is very important. During the last two years, WBREDA has completed collection of wind data for the State of West Bengal. Based on the wind data it is now estimated that 30 MW power could be generated from wind energy in the coastal areas of West Bengal. A 7 MW wind farm is coming up in Frazerganj area of South 24 Parganas district, under the wind energy of programme of WBREDA.

BIO-ENERGY PROGRAMME :

Bio-energy programme has a special relevance in the village areas of West Bengal. The cattle population of West Bengal is very high. According to the estimate about 10 lakhs biogas plant could be installed in the State of West Bengal. WBREDA has so far installed about one lakh number of biogas plants. Every year, WBREDA sets up about 10,000 biogas plants in different villages of West Bengal. In addition, WBREDA is also implementing few programmes on Biomass gasification. A gasifier is being installed at Gosaba Island which will generate 500 KW power for the island people.

IMPROVED CHULHA PROGRAMME :

The improved chulhas are much more energy efficient with 32% of the energy being used up. Thus, it saves fuel cost and helps in forest conservation. WBREDA is implementing this particular programme in the State of West Bengal. About 4 lakhs numbers of improved chulhas are now in operation in the State. Every year, the number is increasing by about one lakh.

MINI & MICRO HYDEL POWER PLANT :

In the Himalayan belt of West Bengal about 100 MW power could be generated through mini and micro hydel power sources. WBREDA has already started implementation of the project related to Mini & Micro hydel. Already three nos of mini & micro hydel plants with installed capacity about 550 KW have been installed in the State. A large number of such sets are being installed in the State of West Bengal by WBREDA which will increase the installed capacity of mini and micro to 10 KW within next three years time.

SPECIAL PROGRAMME BEING IMPLEMENTED BY WBREDA :

Some special programmes are being implemented by WBREDA

- Setting up of a 3 MW capacity Tidal power plant at Durgadwani, Gosaba of West Bengal
- at Durgadwani, Sundarbans of West Bengal (first of its kind in the country).
- Setting up of an Energy Park at Calcutta
- Converting Sagar Island into Energy Island.

1.3 About Gherzi Eastern Limited

GHERZI EASTERN LIMITED, as an associate of GHERZI ORGANISATION, Zurich, was incorporated under the Companies Act, 1956 in India, in May 1960. The Indian promoting company was NOWROSJI WADIA AND SONS, a holding company of THE BOMBAY DYEING & MFG. COMPANY LIMITED.

In its successful operations over the last three decades, GHERZI has gained extensive exposure to environmental, water/air pollution and infrastructural developmental projects in India, Bangladesh, Sri Lanka, Nepal, Muscat, Thailand, Indonesia and Uzbekistan (erstwhile USSR).

GHERZI has on its roll, a complement of over 250 experienced management consultants engineers, architects and other technicians and provides, under a single roof, all the disciplines like planning, feasibility study, regional planning, architectural, structural engineering, water supply, drainage, sewage, EIA, effluent treatment and disposal, water treatment, electrical installation, HVAC, and utility piping. GHERZI has a formidable team of planners, designers, project managers, construction managers and project engineers, who have been groomed in the implementation of any complex project under stringent time and cost parameters. To operate effectively in a vast continent like India, GHERZI has its regional offices in New Delhi, Calcutta, Madras, Bangalore, Guwahati and site establishments in interior locales.

GHERZI, with its exposure to projects in developing countries, vast experience and strong inhouse expertise, is in a position to meet any challenging assignment. Moreover, GHERZI has, through its principals, GHERZI ORGANISATION, Zurich, ready access to the latest technological know-how from the west.

GHERZI provides comprehensive consultancy services from initial study for project concept, feasibility study, investment decision planning, right up to implementation, project management and supervision.

The services include :

- Concept planning;
- Preliminary investigation;
- Pre-investment study;
- Site investigation survey, environmental impact assesment and master planning;
- Project profile, preliminary design and techno-economic feasibility study;
- Conceptual designs and documentation,
- Detailed engineering in architectural, structural, electrical, HVAC, material handling, environmental handling, mechanical, plumbing, solid waste disposal and allied infrastructure,
- Bid documents, award of construction contracts,
- Construction management,
- Time, cost and resource management monitoring and reporting;
- Final inspection, testing and commissioning;
- Maintenance management;
- Software support for operation
- Financial management;

Specialisation

- Architecture,
- Land use planning;
- Urban development and infrastructure facilities;
- Town planning and country planning, environmental engineering, sanitary plumbing, water treatment, waste water treatment, sewage disposal and recycling of water, environmental impact assessment;

- Solid waste disposal planning, treatment and recycling of waste water and sewage;

- Municipal engineering, O & M planning;
- Health care, hospital planning;
- Electrical and mechanical engineering;
- Fire detection and protection engineering;
- Industrial structures - design, development and implementation;
- Housing and commercial buildings - designs, development and implementation;
- Cotton and synthetic textile units - market survey, feasibility study, technology identification, implementation and commissioning;
- Hotels;
- Pharmaceutical and chemical factories;
- Satellite township and urban planning, strengthening of operative systems;
- Assets and earning valuation of industries, hotels, housing and other properties;
- Strategic planning for industry and corporate structure;
- Systems and software;

1.4 About TERI

The Tata Energy Research Institute (TERI) was set up in 1974 at the initiative of some Tata companies, spearheaded by Tata Chemicals. This Institute studies and seeks solutions to the immense problems that arise consequent to the rapid depletion of natural resources, and the serious environmental hazards that result from their use. Every stage of the energy cycle is examined—extraction, generation, transmission, distribution, and usage—with the focus on the environmental impacts at each stage. TERI's ultimate objectives are to reduce adverse impacts and assist in the conservation of natural resources by improving operational techniques, and wherever possible, by development and substitution of renewable energy technologies for those dependent on non-renewable resources.

TERI is currently active in the following broad fields of research: energy-environment policy analysis, energy engineering and technology, including renewable energy; forestry and rural energy systems; and biosciences, including tissue culture propagation of trees. Programmes in each of these areas attack problems at several levels and scales. For instance, studies on smoke pollution in rural kitchens and studies in cell and protoplast cultures represent TERI's range at the micro-level; and the development of mathematical models to depict and simulate the entire country's energy-economy system in 2001 and beyond is an example of work at macro-level.

To complement its research and training activities, TERI also publishes literature on energy and the environment, ranging from abstracting services to in-depth scientific reports; conference proceedings to books, newsletters to primary journals. These efforts at information dissemination are given an added fillip by state-of-the-art computer databases, a comprehensive library, and audiovisual case-studies. TERI's training programmes range from those aimed at the owners of improved chulhas and biogas plants to those that involve policy makers and senior civil servants.

The Institute's brief is wide and varied. Its activities range from biotechnology research dealing with cell and protoplast cultures at the micro-level, to the development of mathematical energy-economy models is for the entire nation at the macro-level. The Institute receives support from Central and State Governments, and from numerous international organizations such as the World Bank, the Asian Development Bank, the United Nations University, the Ford Foundation, etc

The Institute has grown from strength to strength and is now poised for the twenty-first century. It owes its success to the professional vitality of its staff, a simulating work culture and a sense of self-imposed discipline—essential prerequisites in the pursuit of excellence.

2. Objectives

The design of the building envelope directly influences its space conditioning requirements and potential for using passive solar energy. Through the appropriate selection, sizing and organization of materials and products into building surfaces and spaces, the building becomes an energy efficient filter between the outside and indoor environments.

Consideration of energy consumption and of the outdoor environment during the architectural design process is necessary due to rising energy demand and costs and increasing loads on the natural environment. Therefore, energy and environment factors must be considered in the early stages of a building design. The objective of an energy efficient building design are to:

1. Minimize energy demand and environmental impact: An adequate evaluation of bi-climatic impacts whether they are an energetic asset or a liability for the individual design. It is necessary to identify potential conflicts and contradictions of technical and economic considerations.
2. Maximize the use of renewable forms of energy: Renewable energy systems e g. solar hot water systems and solar photovoltaic (PV) system, can be economically employed to reduce the consumption of the conventional energy.
3. Optimize total energy and auxiliary space conditioning systems: Designing the functional organization of the building and selecting the most suitable materials and energy efficient building systems. Optimization of energy savings in the lighting energy consumption by exploiting the potential of daylight integration.

3. The site

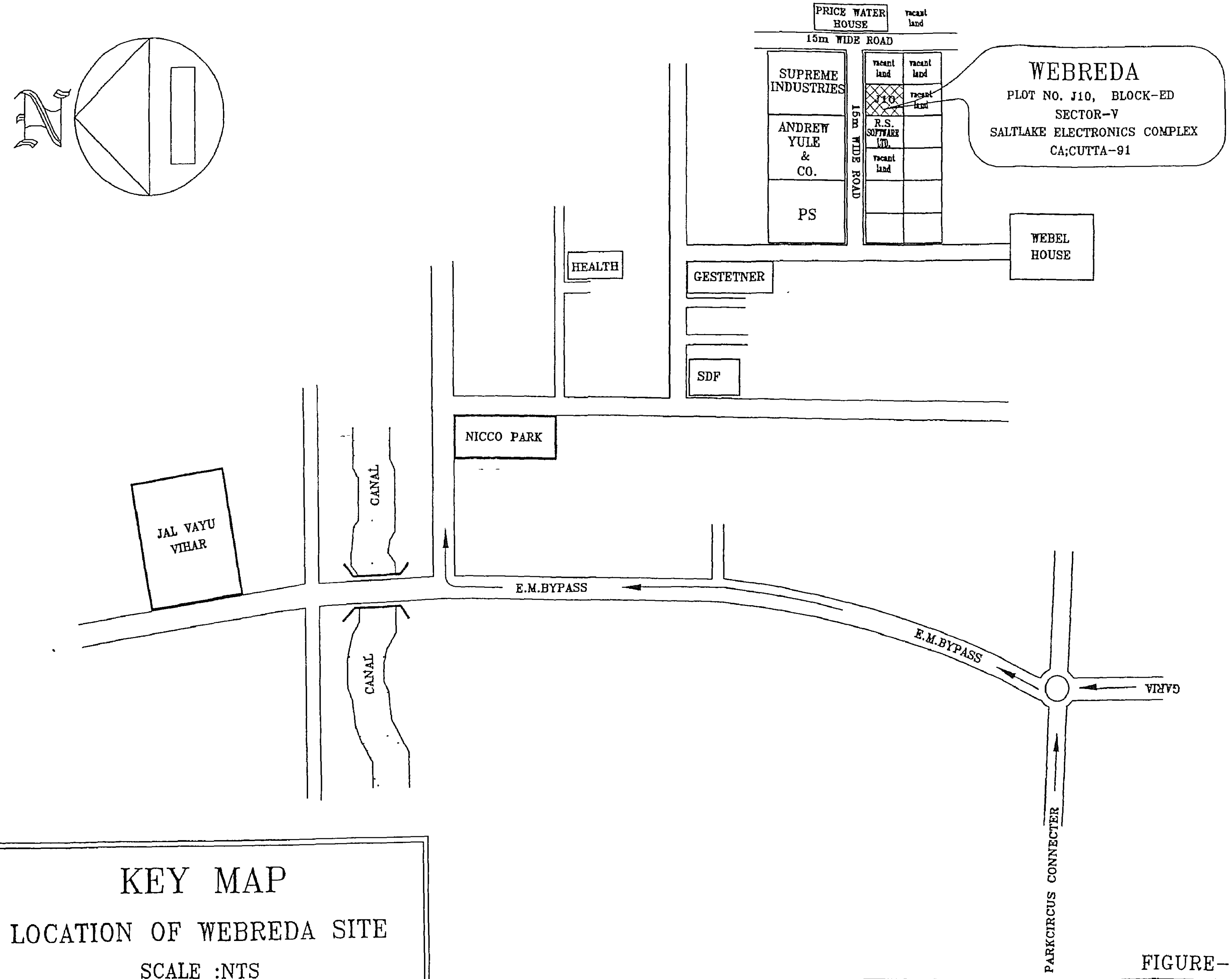
The proposed site for the office complex is located at Plot No. JI 10, Block ED of Sector V, Salt Lake City, Calcutta - 700 091. This is at the Eastern periphery of Calcutta Metropolis within the Salt Lake Electronics Complex. A key map is enclosed for reference (Figure-1).

3.1 Land and soil characteristics

This is understood by observation that the entire plot is a flat land with sandy soil mixed with garbage, brickbats, etc. The sub-soil stratum below this layer consists of loose silty fine sand with decayed vegetation according to the investigation report. This has been the case also with the neighbouring plots at the site.

3.2 Neighbourhood - planned for future

There are vacant lands at the adjacent north and east side of the proposed plot. Three storied factory-cum-office building of price water house is located next to the bare land at north side. A company called R S. software which basically deals with computer software has acquired a plot adjacent to the proposed site at its south. The factory-cum-office building of Supreme Pvt. Ltd, which produces Coca-Cola crates has its front side located towards the road at its west. The electronics factory of Andrew Yule & Co. Ltd and the main office building of West Bengal Electronics Development Corporation are also located in the neighbourhood.



KEY MAP

LOCATION OF WEBREDA SITE

SCALE :NTS

FIGURE-1

4. The climate

Building and climatic conditions are inter-related: climate influences building form, and the building structures create micro-climatic conditions. The term 'energy efficient design' means to consider, to respect and to integrate this natural relationship into modern design, and to comply with certain climatic premises through appropriate decisions concerning the building structure, its material and space conditioning demands.

Mechanical systems are designed to heat or cool a building when outdoor climatic conditions make indoor spaces uncomfortable. One of the most effective ways of saving energy is a strategy of energy conservation and passive design which involves opening the interior to the advantages of the local climatic environment for natural conditioning. This will reduce the dependence on mechanical systems.

4.1 Climatic definitions

A study of the climate and local environment is the first step towards a building design, and needs as much attention as to the planning and other urban legislation related to the site. From the solar point of view, understanding the environment requires a working knowledge of the site's climate which can be defined in terms of the following parameters.

- Temperature
- Humidity
- Wind speed and direction
- Precipitation
- Solar radiation levels, and
- Degree-day (for cooling in our case)

Hourly data of the year 1994 for these parameters (except degree-days) was purchased from the Calcutta regional office of India Meteorological Department. Smaller missing sequences in the year long data series have been filled with interpolated data. Both horizontal (previous and later hours of a day) as well as vertical (previous and later days at the same hour) have been used to generate data. Long missing sequences have been left as such and reported in the following analysis.

4.2 Seasons

The climate of Calcutta can be divided broadly in three distinct seasons:

Summer:March, April, and May
Monsoon. June, July, August, and September
Winter: December and January

The months of February and October are pleasant from thermal point of view. The climatic parameters are discussed below in detail.

4.3 Representative weather data of Calcutta

In order to understand these variables, they have been plotted in figures 3-12 for one entire year (1994). It would be observed in these figures that Calcutta belongs to warm and humid climatic zone of the country (shown in Figure - 2), which is characterized by high monthly mean temperatures (> 30°C), and high humidity (> 60% Relative Humidity) for major part of the year. The following parameters give an idea of the climate of Calcutta [Bansal and Minke, 1995].

Latitude : 22° 32'N
Longitude : 88° 20'E
Altitude : 6.0 m above sea level
Annual mean temperature : 27°C
Annual range of mean temperatures : 9.7°C
Total annual rainfall : 146 cm
Annual global solar radiation 16.2 MJ/m^2/day

Temperature

The daily average temperatures indicate in Figure - 3 that the building would require cooling for major part of the year (temperatures more than 30°C). A temperature check relative to human comfort for each month (Figures 4 and 6) produces the following results.

	Cold	Cool	Comfort	Warm	Hot
January			●		
February			●		
March				●	
April				●	
May					●
June				●	
July				●	
August				●	
September				●	
October				●	
November			●		
December			●		

The air temperature can rise up to 40°C in the beginning of summer, and can be as low as 10–12°C for short duration during winter. Monthly average temperature are shown as bars in Figure - 4.

Humidity

The humidity levels are very high in Calcutta throughout the year as seen in Figure 6 where the monthly average relative humidity (RH) remains above 70% for 10 months. The daily average of RH is close to 100% for the entire monsoon season (Figure - 5) The RH data is missing for 31st January.

Radiation

Global radiation has small variance from the mean value of 16 MJ/m^2/day except for the months of March, April, and May when the radiation levels are as high as 22 MJ/m^2/day (Figure - 7). The daily sum of global radiation shows an entirely different characteristic (Figure- 8) in monsoon marked by frequent and higher deviations from the mean value. The presence of clouds is indicated throughout the year, and therefore, bright sunshine hours in Figure - 9 vary considerably in all the seasons. Bright sunshine hours are further restricted during monsoon. The graph also shows that radiation data for 5 days (7th–11th) in the month of December.

Precipitation

Calcutta receives high rainfall in the monsoon season as shown in Figure 10. The total rainfall can reach 380 mm during a month and the monsoon season often extends till the end of September, as revealed by climatic history of Calcutta.

Hail storms and thunder storms are usually reported in the beginning of monsoon.

Wind speed and direction

Mean monthly and daily wind speeds are plotted in Figures 11 and 12 respectively. Data for November and December of 1994 was, however, not available from the Meteorological Department.

The prevailing wind directions during morning and evening for each month are also shown in the bar chart.

Degree-days for cooling

Degree days for cooling have been calculated with a base temperature of 24°C for each month of year (1994) and plotted in bar chart of Figure 13 for the summer months. Degree days are used to estimate the energy required by the air-conditioning plants. However it should be kept in mind that the procedure is intended to recognise the part of energy transferred out of a building not including internal sources such as lights, equipments, occupants and solar gain; although energy transferred out would be proportionate to the difference between interior space temperature and the outside temperature (ASHRAE HAND BOOK).

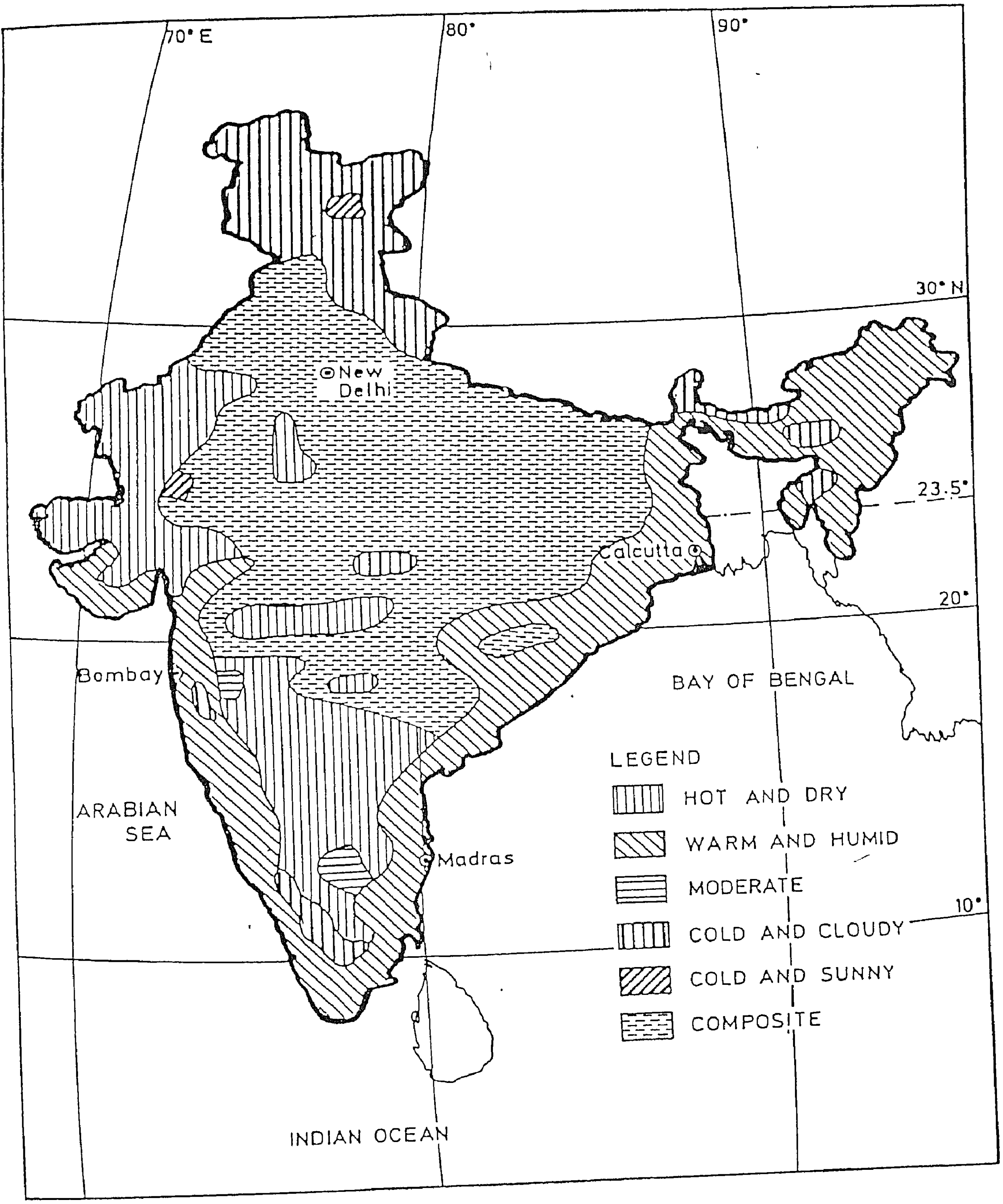


Figure - 2 : Climatic Zones of India

Fig 3: Average Daily Temperatures

Calcutta 1994

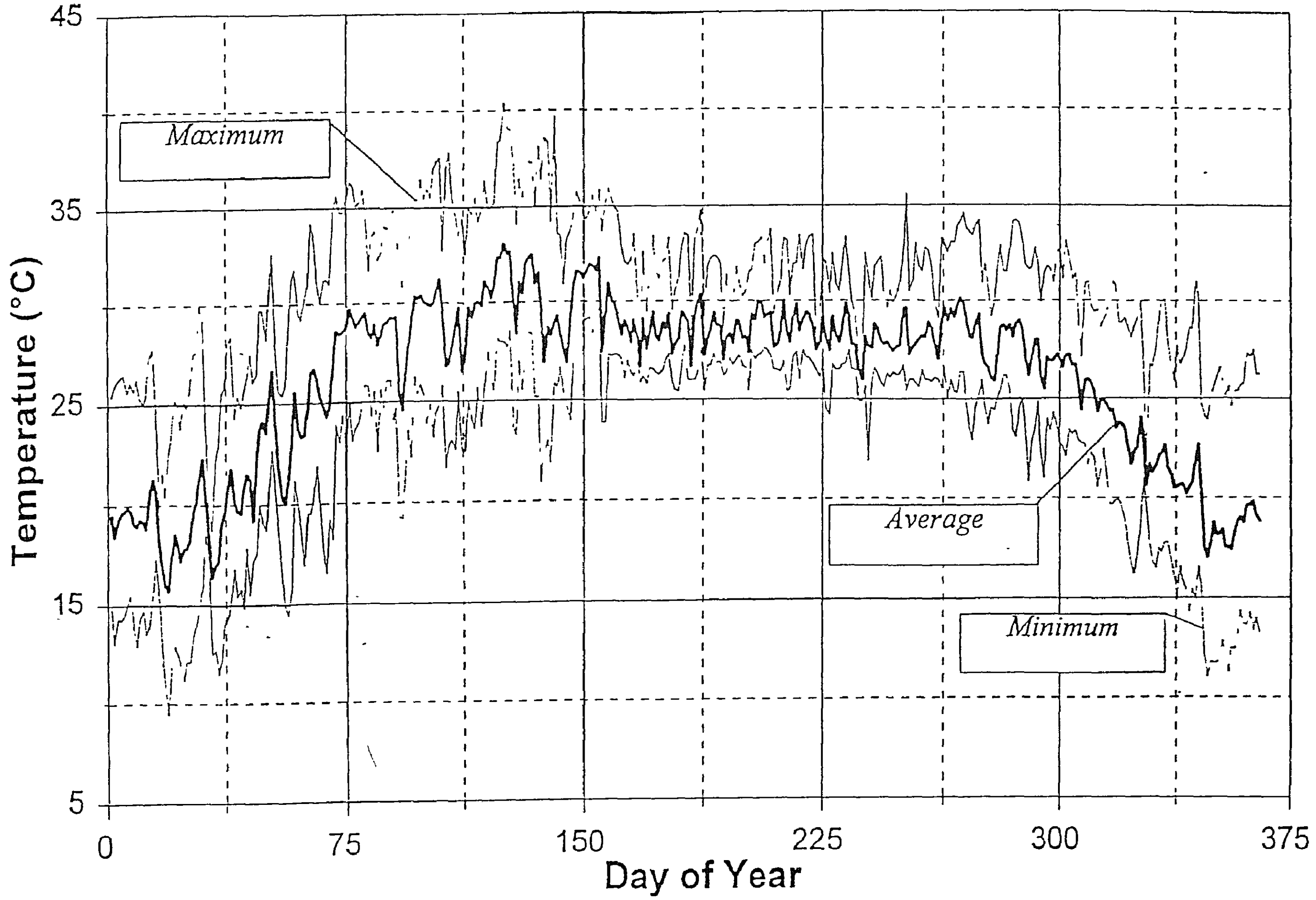
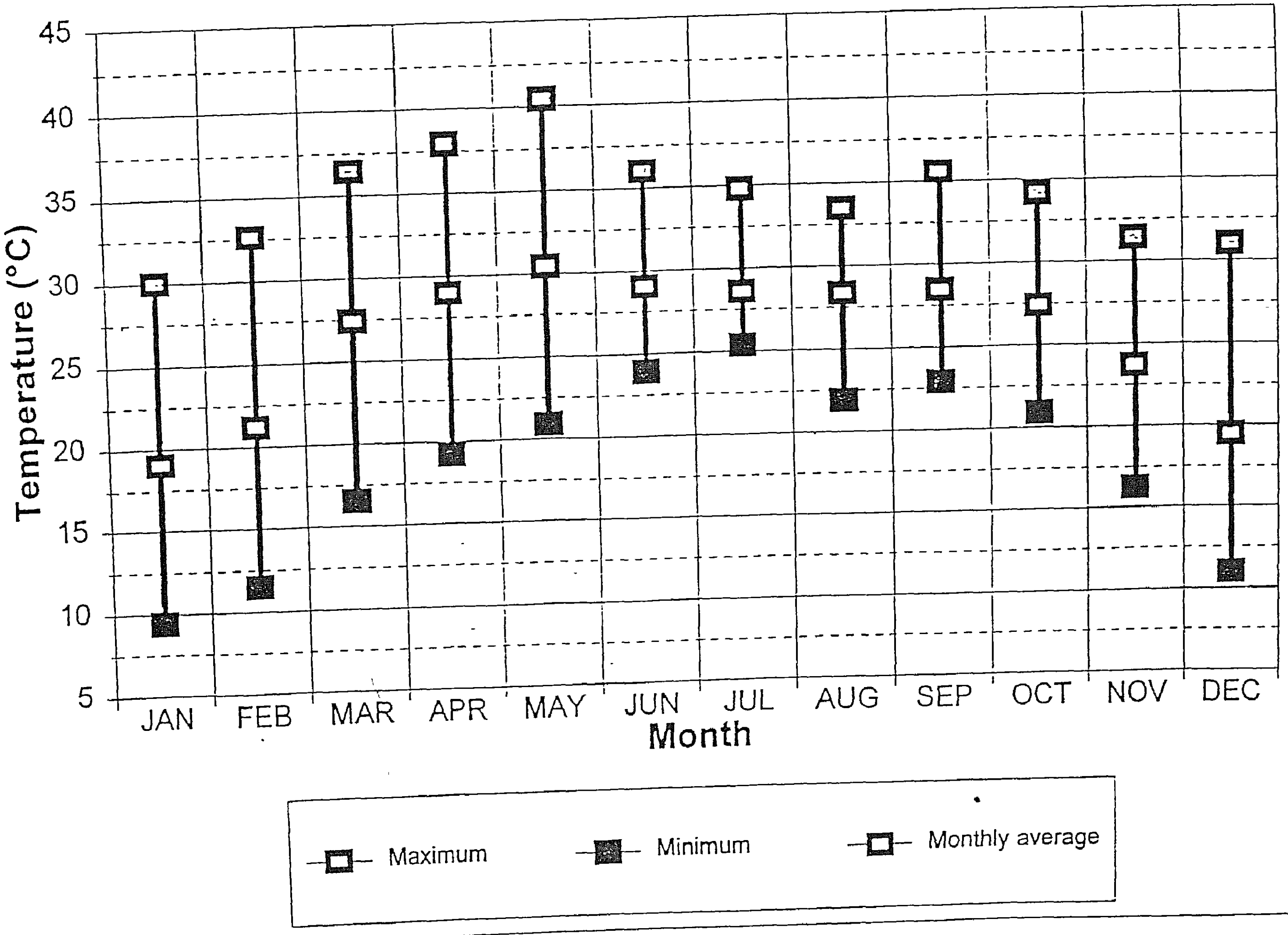


Fig 4: Average Monthly Temperatures

Calcutta 1994

Maximum and Minimum are the highest and lowest temperatures respectively recorded during that month



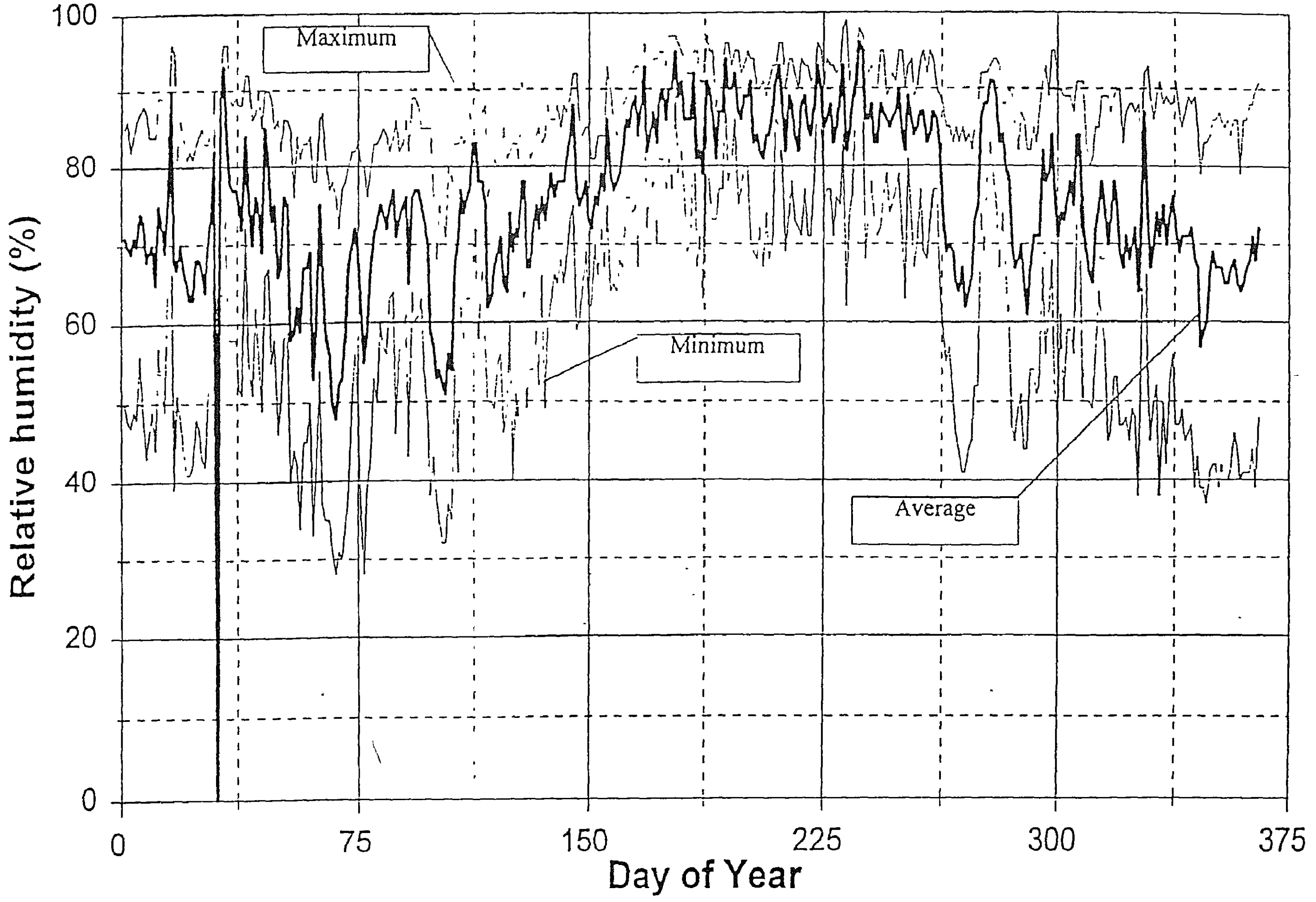


Fig 5: Daily Average RH

Calcutta 1994

Fig 6: Average Monthly RH

Calcutta 1994

Maximum and Minimum are the highest and lowest values of RH respectively recorded during that month

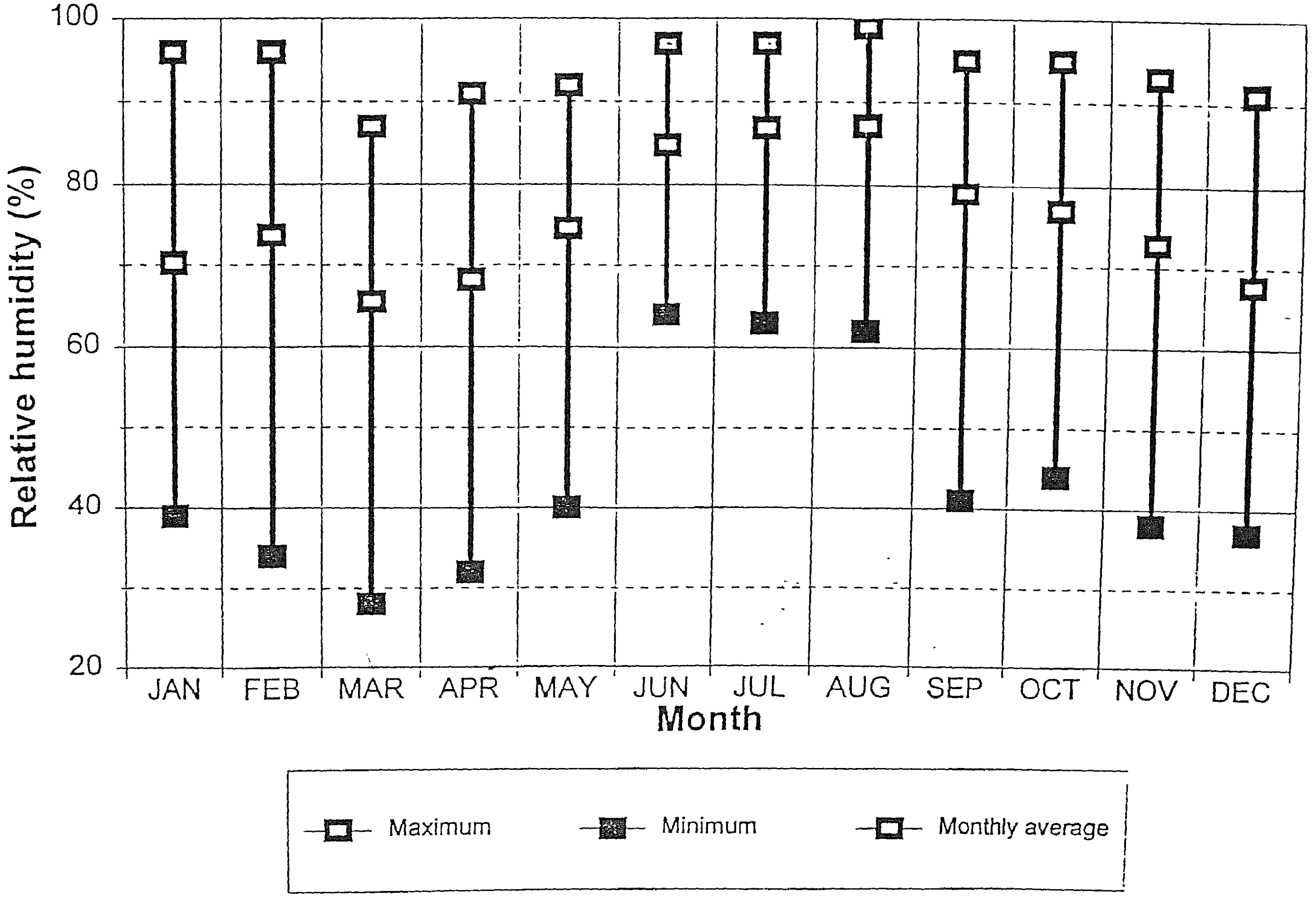
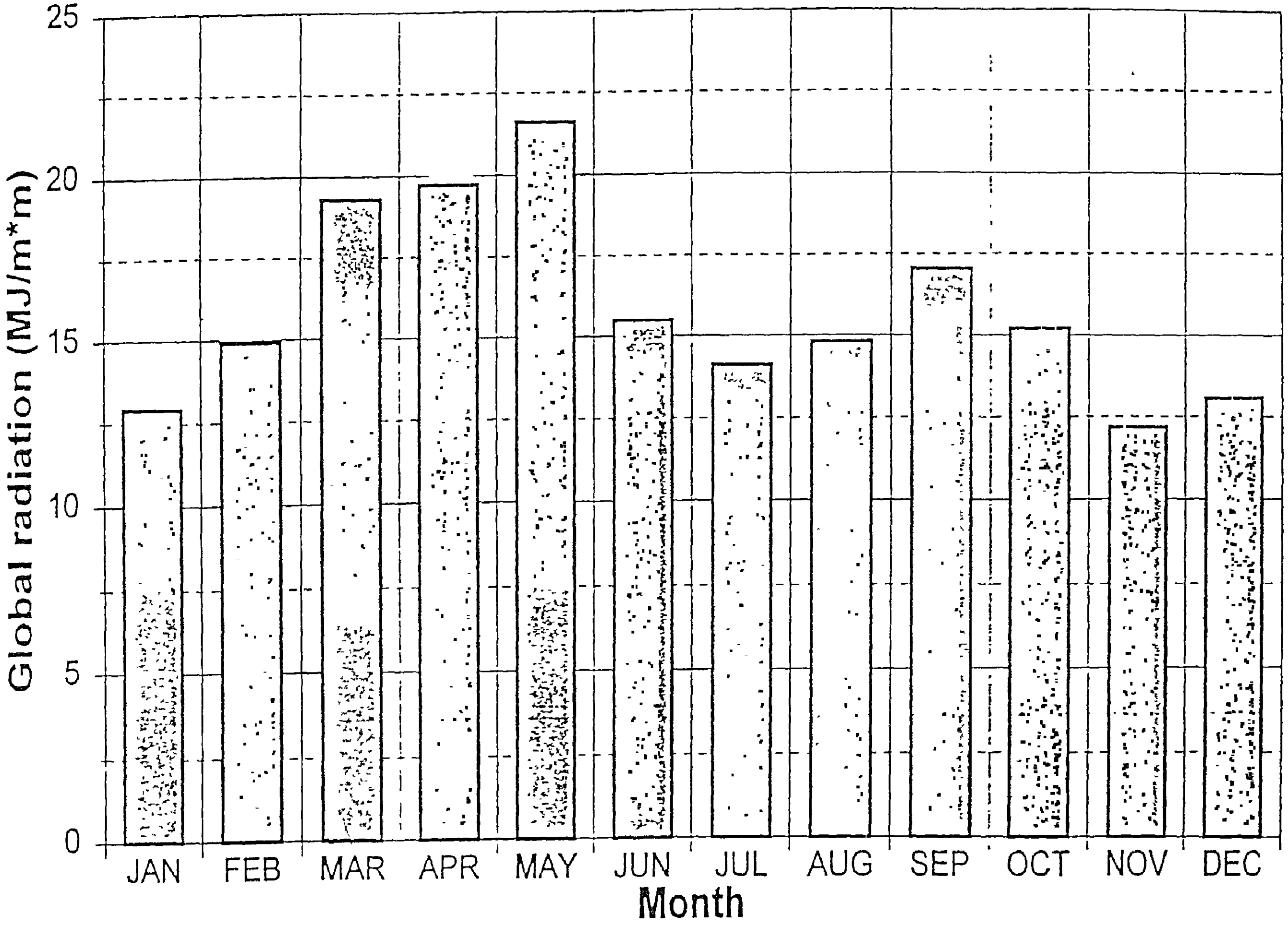


Fig 7: Av. Monthly Global Radiation*

Calcutta 1994



* Monthly mean of daily gobal radiation on horizontal

Fig 8: Daily Global Radiation

Calcutta 1994

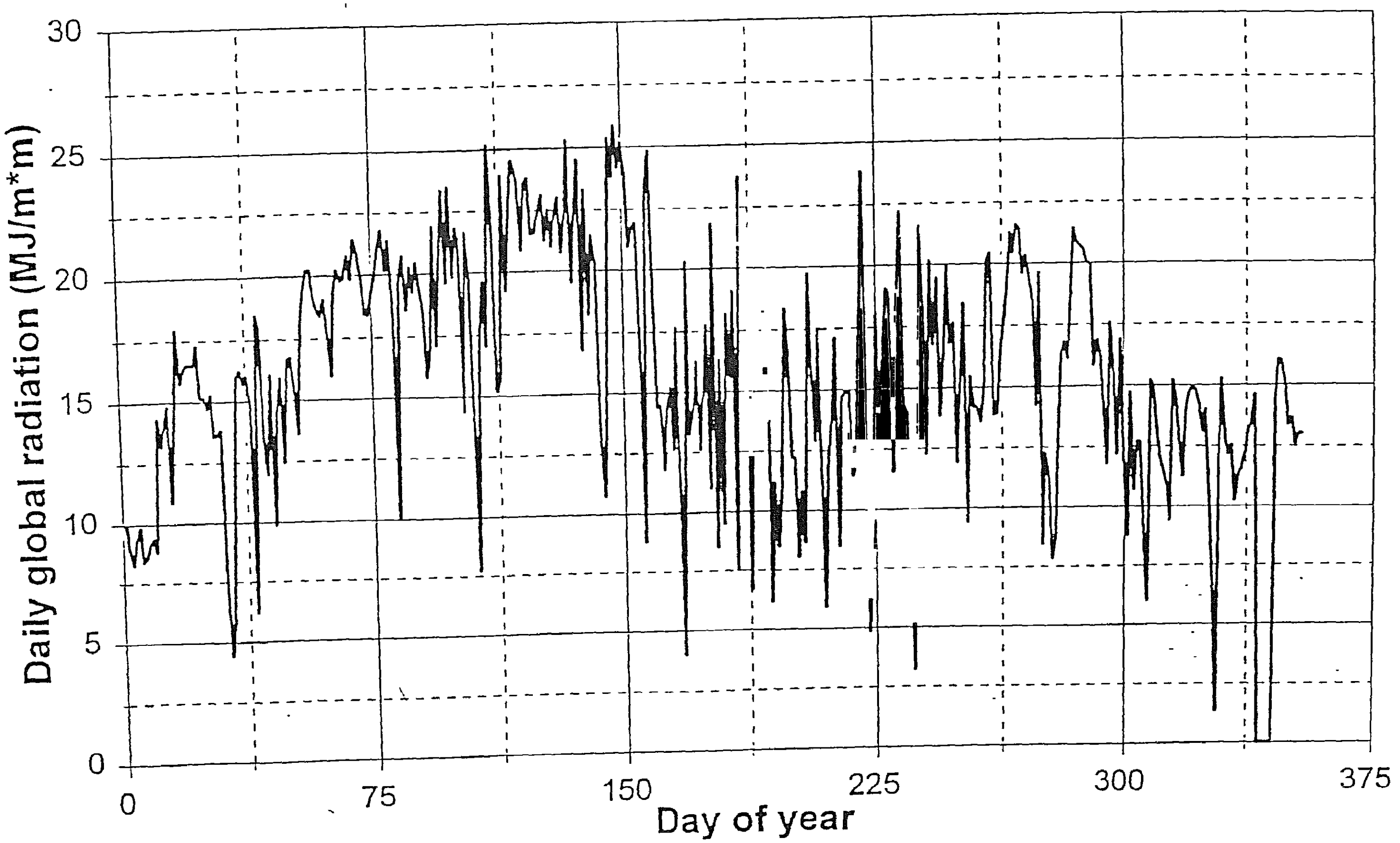


Fig 9: Bright Sunshine Hours

Calcutta 1994

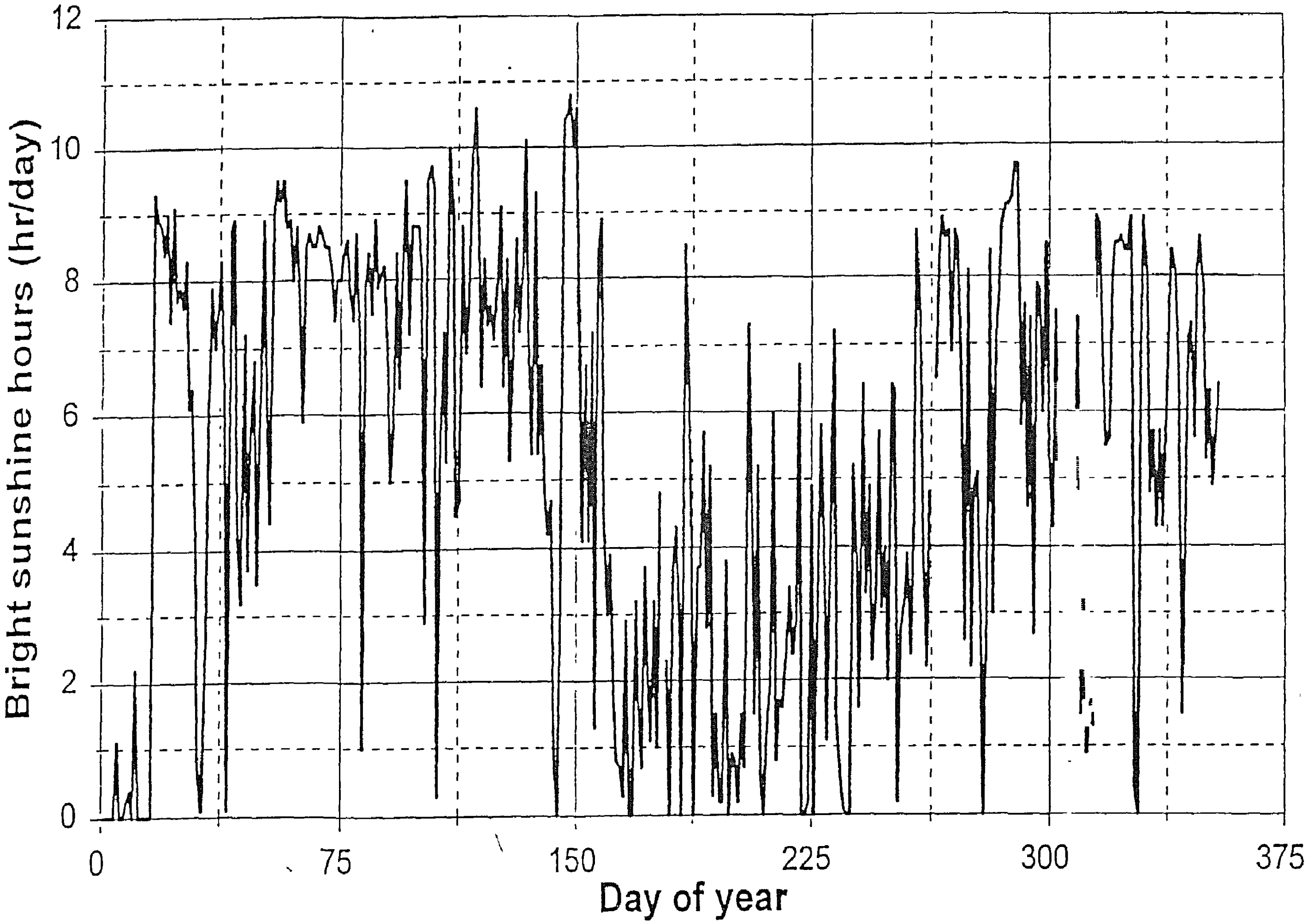


Fig 10: Monthly Rainfall

Calcutta 1994

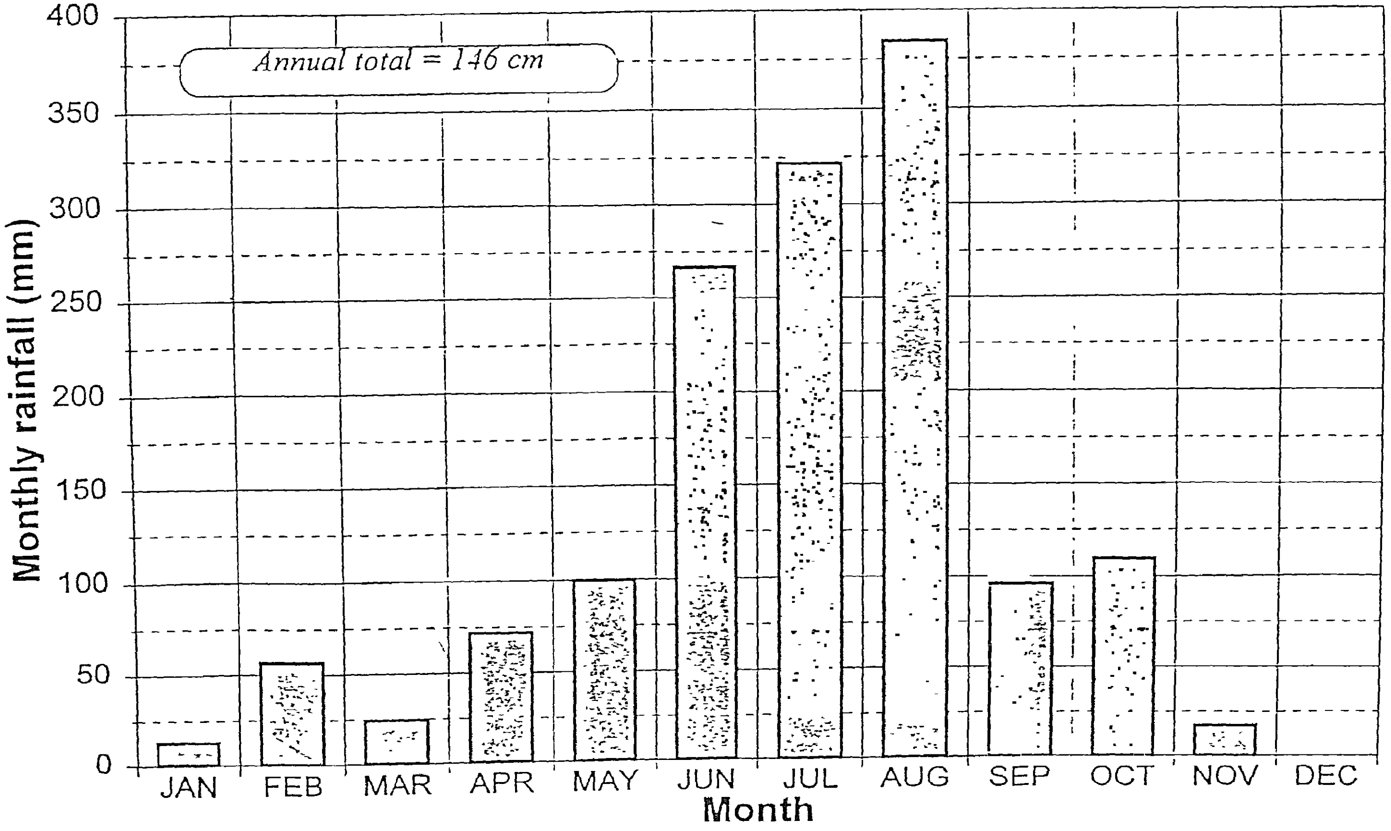


Fig 11: Mean Monthly Wind Speeds

Calcutta 1994

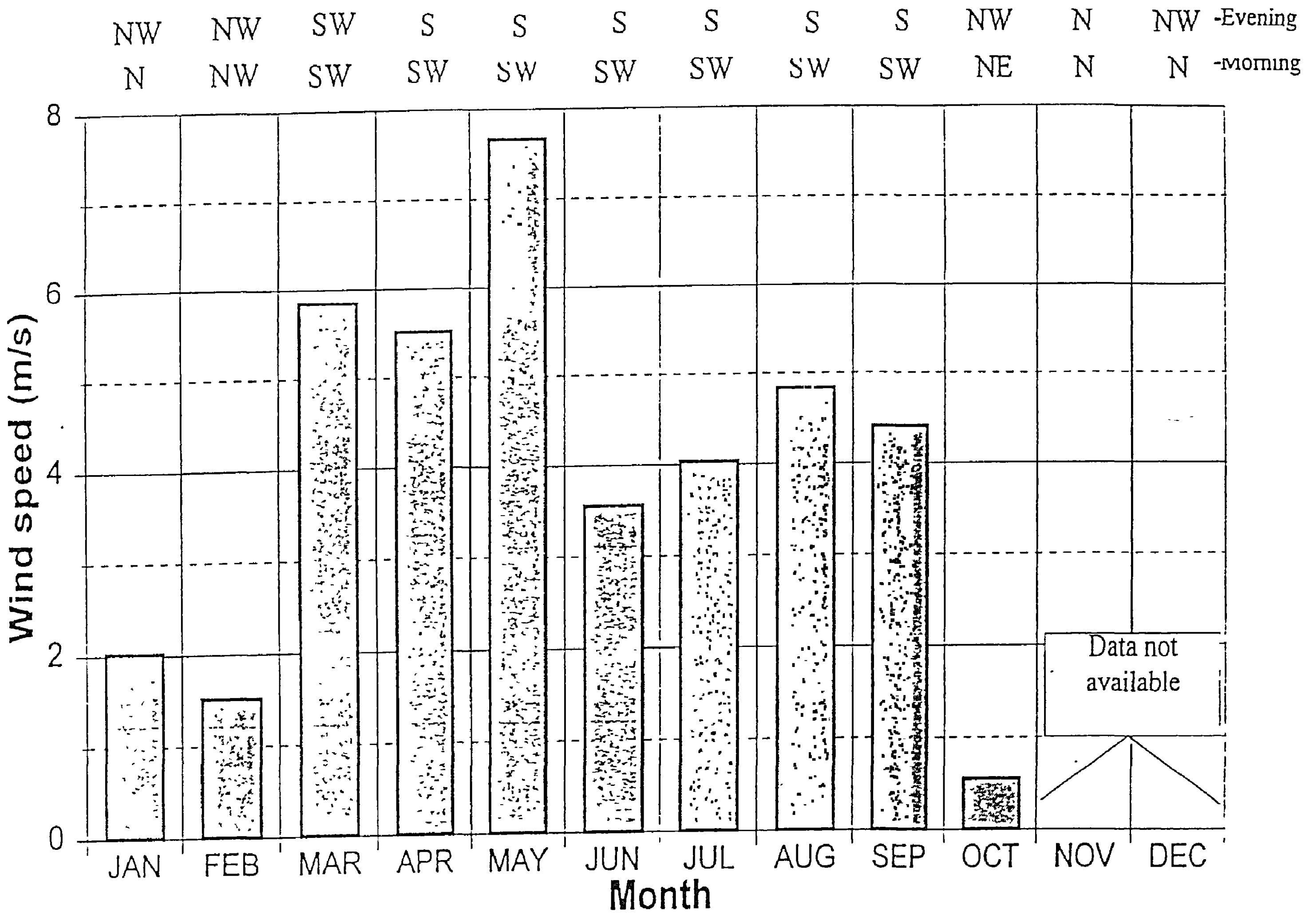


Fig 12: Mean Daily Wind Speeds

Calcutta 1994

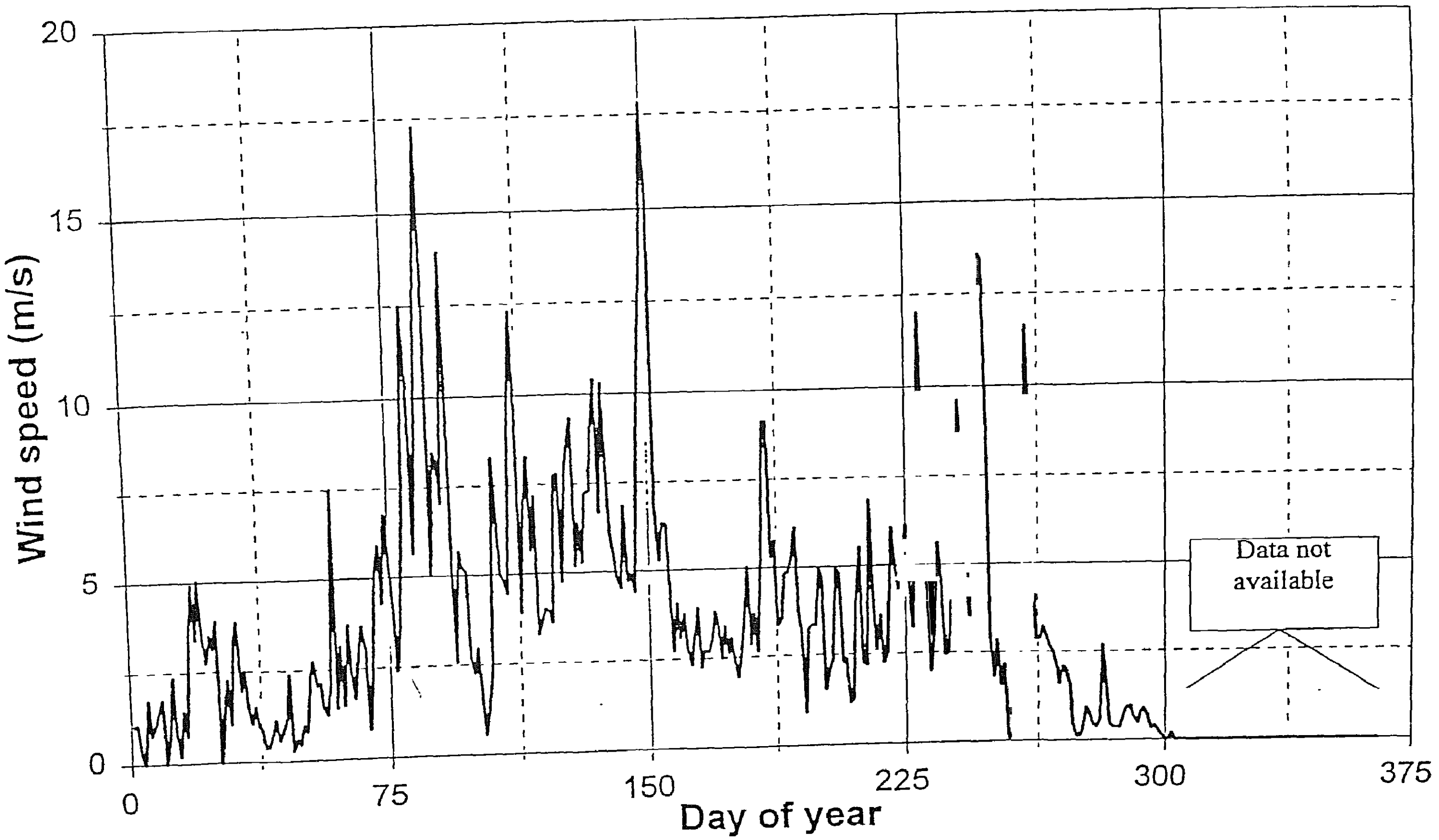
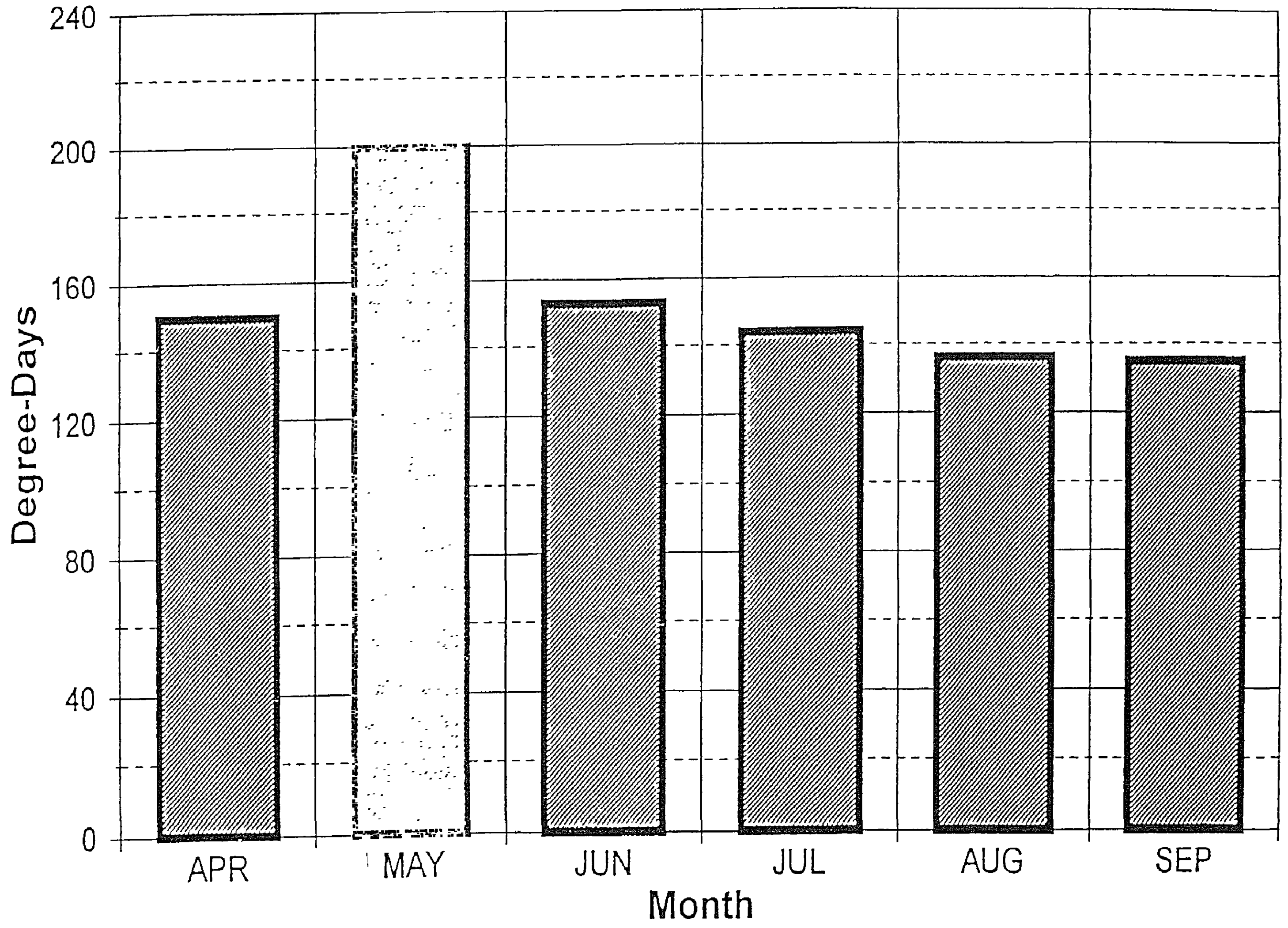


Fig 13: Degree-Days for Cooling
Calcutta 1994



5. Evolution of concept

The enormous amounts of energy consumed in office building are cause for concern for building designs, as well as for the organizations using these buildings. For this reason, WBEREDA decided to incorporate energy efficiency in the building design, to use low wattage luminaires, to employ automatic switching of lighting system and to use appropriate non-conventional energy systems. To facilitate such energy efficiency, the building has been designed using the basic concepts of solar architecture. The building layout, internal planning and selection of material have been carefully considered in order to reduce the energy consumption Efforts have been made to maximize the use of on-site energy resources for right illumination, favourable heat transmission and air-circulation.

The land acquired by WBREDA is a rectangular plot longer in east-west direction. As per the Client's requirement the building shape and the building orientation was made E&W in longer direction. This however has been taken as a positive feature in the proposed planning.

To form a concept for the proposed building, following parameters were taken into consideration (Please see Figure 14 for illustrations)

1. East, west and south side must be protected from direct sun.
2. Ground surface must not reflect and radiate heat.
3. In hot and humid climate, natural ventilation must be of highest priority. There should be ample provision of cross ventilation.
4. Natural elements like vegetation and water must be utilized to enhance energy efficiency.

Following these parameters, the basic design of the building has been conceived with following main features.

1. The form of building plan has been conceived as a rectangle. Shorter sides of the rectangle are facing east and west to reduce heat gain. Air-conditioned areas were to be kept on northern side of the building. The walls on east and west face will have no fenestration. The areas

which were not used frequently like store, staircase, toilets etc. might be placed on eastern and western side as buffer against direct solar heat.

2. Ground surface on the southern and eastern side of the building would be covered with grass or water to minimize heat gain from the surroundings.
3. Non-air-conditioned areas are planned to be located on the southern side to take advantage from the prevailing wind during hot and humid period. For better cross ventilation, portion of roof would be raised and used as solar chimney. Southern face of the wall must be protected by overhangs.
4. Use of vegetation and water bodies to modify the micro-climate.
5. The building is virtually divided in two parts in North and South block serviced by a corridor in between. To best utilize the prevailing south breeze, a water body has been created in south part of the building at ground level which has in turn increased the aesthetic value of the concept. The south breeze blowing over the water body will get trapped at the bottom of the building and the same is vented through the building with suitable cut outs, ventilators, windows, so that the cool south breeze can blow up to deepest position of the building. The calculated opening provided will act as vent shaft taking care of cross flow of south wind and taking out the hot air from the non A.C. areas.
6. All the circulation spaces like staircase, lobby, corridors are naturally lighted by way of raised roofing and heat insulated but clear glass. It is also proposed to use the similar glass for good quality windows in other parts of the building.
7. A test bed has been provided at south side of the plot in open space of approximate area of 1800 sq. ft.

Vehicular movement has been restricted by providing the drive way in north and east parts of the building, and south part is kept free for the demonstration of renewable energy systems and other R&D activities of WBREDA.

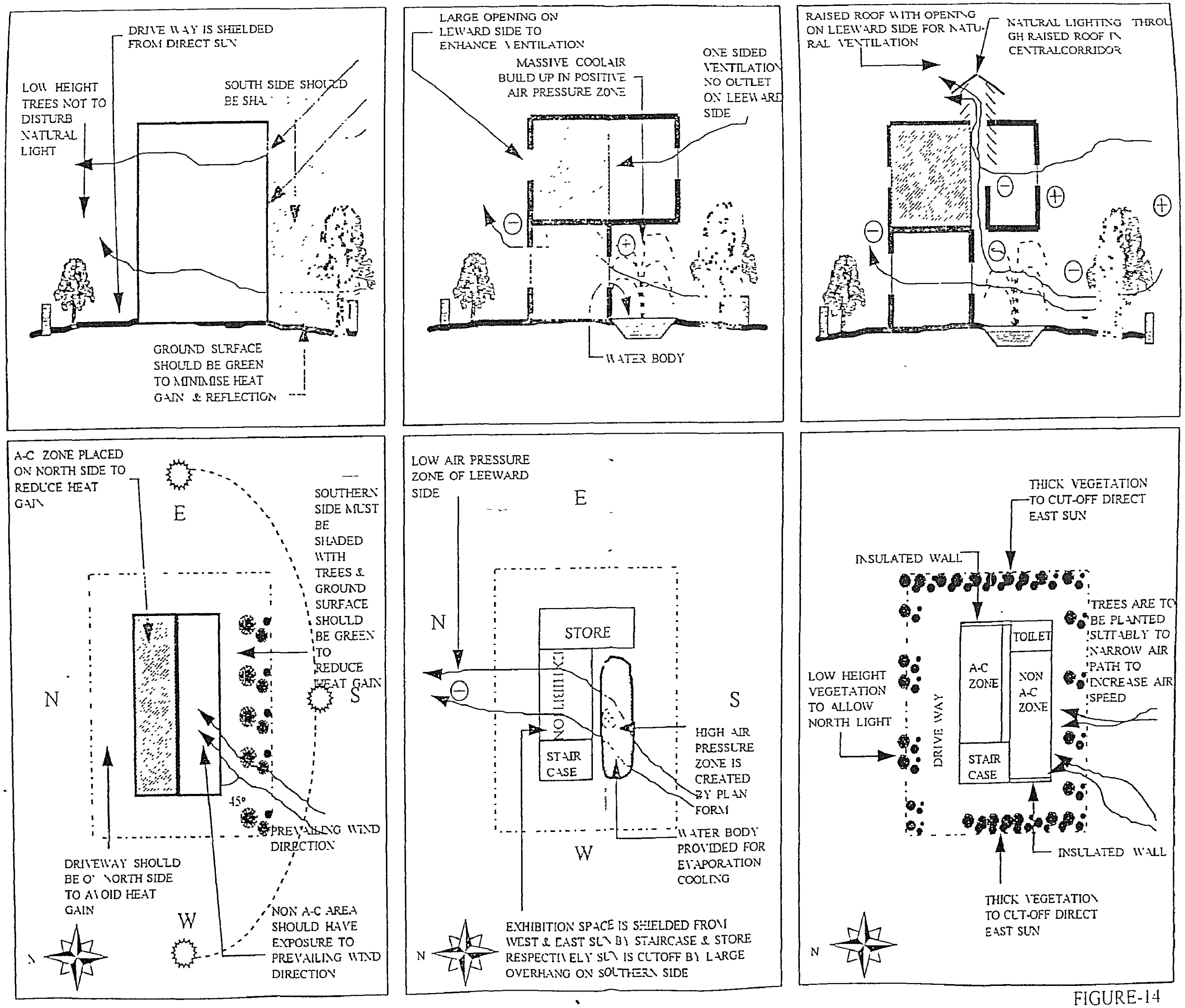

DRIVE WAY IS SHIELDED FROM DIRECT SUN
LOW HEIGHT TREES NOT TO DISTURB NATURAL LIGHT
SOUTH SIDE SHOULD BE SHA
GROUND SURFACE SHOULD BE GREEN TO MINIMISE HEAT GAIN & REFLECTION
LARGE OPENING ON LEWARD SIDE TO ENHANCE VENTILATION
MASSIVE COOLAIR BUILD UP IN POSITIVE AIR PRESSURE ZONE
ONE SIDED VENTILATIO NO OUTLET ON LEEWARD SIDE
WATER BODY
RAISED ROOF WITH OPENING ON LEEWARD SIDE FOR NATURAL VENTILATION
NATURAL LIGHTING THROUGH RAISED ROOF IN CENTRALCORRIDOR
A-C ZONE PLACED ON NORTH SIDE TO REDUCE HEAT GAIN
E
N
S
W
SOUTHERN SIDE MUST BE SHADED WITH TREES & GROUND SURFACE SHOULD BE GREEN TO REDUCE HEAT GAIN
45°
PREVAILING WIND DIRECTION
DRIVEWAY SHOULD BE ON NORTH SIDE TO AVOID HEAT GAIN
NON A-C AREA SHOULD HAVE EXPOSURE TO PREVAILING WIND DIRECTION
LOW AIR PRESSURE ZONE OF LEEWARD SIDE
E
N
S
W
STORE
EXHIBITION
STAIR CASE
HIGH AIR PRESSURE ZONE IS CREATED BY PLAN FORM
WATER BODY PROVIDED FOR EVAPORATION COOLING
EXHIBITION SPACE IS SHIELDED FROM WEST & EAST SUN BY STAIRCASE & STORE RESPECTIVELY SUN IS CUTOFF BY LARGE OVERHANG ON SOUTHERN SIDE
N
THICK VEGETATION TO CUT-OFF DIRECT EAST SUN
INSULATED WALL
TREES ARE TO BE PLANTED SUITABLY TO NARROW AIR PATH TO INCREASE AIR SPEED
LOW HEIGHT VEGETATION TO ALLOW NORTH LIGHT
A-C ZONE
TOILET
NON A-C ZONE
STAIR CASE
DRIVE WAY
INSULATED WALL
THICK VEGETATION TO CUT-OFF DIRECT EAST SUN
N

FIGURE-14

6. Design Strategies

A study of the climate of Calcutta shows that there are about 6 months (April-September) during the year, that require mechanical cooling of the building in order to provide thermal comfort. Various strategies have been suggested, as outlined below, to cool the building, where an effort has been made to use the on-site heat resources and sinks to allow the heat exchange between the building and the surroundings. **The energy consumption would be drastically reduced due to these design strategies, and it is in this sense that the building would be called an energy efficient building.**

6.1 Modification of micro-climate through natural means (land scaping)

Land scaping is been considered as a very effective means for the modification of the micro-climate. Landscaping elements like vegetation and water bodies have been considered judiciously in this building, whose absorptive and radiative capacities are useful parameters to be considered during the planning. As paving materials, in general, have radiative and absorptive capacities, the paved driveway has been provided on the northern side of the building to minimize heat gain. The open land on the southern part of the building would be converted into a grass covered lawn. As radiation from sun can be absorbed by grass which is not a thermal mass, the lawn at the south side of the building should minimize the heat contents of the surrounding environment.

Vegetation has been used in our design also for shading and regulation of prevailing wind in south-west directions Long trees with thick foliage on eastern and western side of the building at close intervals have been proposed to create a barrier to cut off direct sun. On the south face, the trees are placed strategically so that these can cut off direct sun and regulate the velocity of the wind as well. Strategically planting the trees at regular intervals provides a 'narrowing path' for the wind, thereby increasing its speed. On the northern side the trees will be of smaller height to allow natural light to come into the building.

Water plays a significant role in reducing the temperature swings due to its evaporation. Water bodies with fountains at the courtyards have been a common feature to facilitate evaporative cooling. A pond with fountains has been included in the building design. Apart from cooling air, the presence of water body will add to the beauty of the surroundings of the proposed building.

6.2 Reduction in the direct heat gains

Provision has been made for shading the windows on the South side by recessing them by 0.5m from the external surface, which would allow only the diffuse light (day light) to enter the building. No windows are provided on East and West sides which would have been difficult to shade from the direct morning and evening sun. Efforts have been made to reduce the effect of direct solar exposure by reflecting sun rays through glazed tile finish on the roof and white coloured aggregate finish (or Kent tiles) on the walls. In order to maximize the benefits of the proposed strategies, the orientation of the building was carefully selected with least exposed faces on West and East

6.3 Reduction in the indirect heat gains

Conduction heat gains would be reduced by increasing the thermal resistance of the envelope, mainly by the use of thermal insulation in the roof and walls. The insulated walls and roof not only lower the energy consumption but also allow lower mean radiant temperature (effective temperature of room surfaces) to provide better thermal comfort. The suggested construction of the roof has a U-value (thermal transmittance) of 0 4 W/(m^2-K) against 2.2 W/(m^2-K) of the traditional roof, and the insulated wall has a U-value of 0.65 W/(m^2-K) against 2.0 W/(m^2-K) of the traditional exterior wall construction. The insulation will reduce the air-conditioning load by 40%. The ground storage cannot be effectively used for this building because of large water table at the site, but earth berming of the West and North faces up to the sill level has been considered

Good quality (air tight) double glazed windows in the air-conditioned areas and single glazed windows have been recommended to check the unwanted heat gains through infiltration throughout the building, and through conduction in the air-conditioned areas. Double glazed windows are expected to reduce the mechanical cooling load by about 12%.

6.4 Removal of internal heat

A ventilation device has been incorporated in the building design in the form of a solar chimney in combination with evaporative cooling system. The wind prevailing mostly in S-N direction will get cooled by water fountains in the water pond located on the South side, and the cooled air will ventilate the building due to the stack effect caused by the solar chimney. The cool air reaches the first floor after passing through the openings in the ceiling of the ground floor.

The height and the orientation of the windows also ensures ventilation of the ground floor areas.

Air movement inside the building will be enhanced by electrical roof mounted fans as and when required by the occupants.

6.5 Day light integration and energy efficient lighting design

The basic requirement of any lighting installation is to provide sufficient light in the right place at the required time. This provides the occupants the visual comfort i.e. the occupants are able to see and work efficiently without fatigue or strain. In addition, good lighting enhances the appearance of a space and provide a pleasant working environment.

Electric lighting is a substantial energy consumer in an office building and, therefore, represents significant annual costs. An energy efficient lighting installation which carefully considers both the aspects of the installed load and the hours of daily operation, depends upon:

- the efficiency of the various components of the system: lamps, ballasts, luminairs etc., and
- the control strategies and day light availability (and its integration).

The lighting scheme for the WBREDA office building would be designed to provide the desired quality, and the recommended quantity of light as per ISI Standard [ISI 3646 (part II)]. While providing a good colour rendition (cool day light appearance), illumination levels to be provided in different areas of the proposed office are:

- Entrance hall and reception area - 150 Lux
- Conference room and private offices - 300 Lux
- Open plan office - 300 Lux
- Stairs - 100 Lux
- Corridor - 70 Lux

Recommended lighting equipment

- Linear fluorescent lamps (36W Philips Trulight) to illuminate the interior work zones.
- Reception areas, entrance and elevator lobbies, corridors, staircase and other public areas to be fitted with compact fluorescent lamps (CFL). The CFLs are available in different ranges in the market, have good colour rendition and consume about 80% less electrical energy than tungsten lamps.
- Many modern luminairs contain carefully designed reflector systems (Batwing mirror optics) to direct the light from the lamps in the required direction. These allow fewer lamps or luminairs to be used to produce a given illuminance.
- Good quality ballasts would be used to control all discharge lamps. High frequency electronic ballasts can save upto 20% energy in the fluorescent lamps, and soften the starting conditions which renders a longer life to the lamp.

Day lighting

Day lighting, within a building, has a major effect on the appearance of the space, and can have considerable energy efficiency implications. The building occupants have preferred a well day-lit space provided the glare and overheating are avoided.

The windows provided on the North and South facades are adequately sized, to provide sufficient day light for most of the day and throughout the year, except during the monsoon period. The sizes of shading devices in form of fixed louvers (overhangs, side fins) have been optimized on the basis of Solar geometry. The entry of day light into the work-areas is enhanced by providing a light-shelf in the South windows. The calculations of the illumination levels due to day light and selected electric lighting assemblies would be done later.

Lighting control

Appropriate lighting controls yield improvements in the lighting energy efficiency. These improvements arise basically from the utilization of the available day light to reduce electric light, and from switching off the electric light when the space is unoccupied. The four methods of lighting control are.

- time based control
- occupancy linked control
- day light linked control
- localized switching

Time signals which can be derived from a variety of devices ranging from the simple multi-position electro-mechanical to solid state switches, are transmitted to the luminaires through communication channels. Local override controls would be provided so that the occupants can restore lighting if necessary.

6.6 Use of renewable energy system

The client has assured that there would be no hot water demand in the building. Although the solar hot water systems would be installed outside the office for demonstration purposes, these systems have not been considered for integration into the building

Solar Photovoltaic (PV) panels which convert sun light directly into electricity, would be integrated into the south facade of the proposed office or on its roof. These panels can provide upto 50% of the total lighting load of 6.0 kW. The electricity generated from these PV panels can be safely used for

- lighting up corridors, entrance and other public areas
- lighting up drive way and mandatory areas at night
- providing emergency lighting in work areas at the time of grid power failure

7. Proposed design of the building

The building has been formulated as a rectangular building of 26.7 M × 17.8 M. The present phase of the building has been considered as G+1 and the other two floors will be built at a later day.

7.1 Required and proposed areas

Various areas of the buildings as required by the client, and the same proposed by the architects are mentioned in the following table.

Ground floor

	Required	Proposed
Store	2000 Sft.	1920 Sft.
Garage	320 Sft.	320 Sft.
Driver's room	150 Sft.	105 Sft.
Exhibition room	500 Sft.	850 Sft.

First floor

	Required	Proposed
Reception-cum waiting room	200 Sft.	105 Sft.
Officers room (including Director's room)*	1000 Sft.	1000 Sft.
Conference room*	400 Sft.	430 Sft.
Accounts section	500 Sft.	440 Sft.
General section	500 Sft.	500 Sft.
Technical section	500 Sft.	500 Sft.
Library, documentation centre*	200 Sft.	320 Sft.
Computer room	400 Sft.	285 Sft.
Cash section	100 Sft.	100 Sft.
Office store room	200 Sft.	125 Sft
Toilet (Gents)	200 Sft.	215 Sft.
Toilet (Ladies)	100 Sft.	125 Sft.
Testing room*	200 Sft	215 Sft.
Lobby, corridor & staircase	600 Sft.	650 Sft.
Total built up area	5000 Sft.	5000 Sft.

* Air-conditioned areas

7.2 The proposed building

As mentioned earlier in the evolution of concept, the shape of the building has been conceived as a rectangle. Shorter sides of the building were facing east and west to minimize direct solar heat gain. The location of the entrance to the building has been determined considering the heat absorption and radiation capacity of paving materials generally used in drive way to reduce heat gain. The driveway has been placed on the northern side of the building as this portion will receive no direct sun. The southern side, the side to receive maximum possible solar heat was to be covered by grass and partly by water body.

Non administrative areas like exhibition, store, etc. have been provided at ground floor while the first floor has been earmarked for administrative activities. Of administrative activities, some areas like Officers' and Director's room, Computer room, Library (Documentation centre), Conference room and Testing room are to be air-conditioned. To reduce heat load, the air-conditioned areas are located at north side

The Exhibition hall in ground floor which was to be ventilated naturally had staircase block and store as buffer on west and east side respectively. As the required area at the ground floor of the building was less than the area at the first floor, south side of the Exhibition hall has been kept open for natural ventilation. An overhang of nearly nine meters has been provided over the windows on the southern wall of the hall. Window area of the south side has been kept lower than window area of the northern wall to enhance wind velocity. Moreover, larger windows on the north side will bring in more natural light to the Exhibition space.

A water body has been provided at the space located at the south side of the building. This will be having fountains running on photovoltaic cells which will be placed on the roof of the building Besides adding to the beauty of the surroundings, this water body will play a great role in making this building more comfortable. The plan form in the ground floor has been conceived with the objective of trapping prevailing southern breeze. A high air pressure zone will be created in that area. The opening on the northern side which is a negative air pressure zone will enhance the velocity of wind The south breeze blowing over the water body and the fountain will get cooled by virtue of evaporative cooling and blow through the Exhibition hall which will make the exhibition hall comfortable during hot period

In the first floor, as mentioned earlier, the administrative requirements are divided in two parts, air-conditioned areas will be provided on the northern side to avoid direct solar heat gain. Natural light from north side is free from direct sun, the air-conditioned area will be having a good amount of day light which will reduce lighting load. Less numbers of artificial lights will reduce heat generated by lumaniares inside the office. The west and east part of the air-conditioned area has been kept solid without any fenestration. Moreover, these walls will be insulated by polyurethene foam (PUF) insulation from inside to reduce the air conditioning load. Large windows with wooden frame and insulated glass will be provided to let in natural light. The false ceiling in the air conditioned portion will be insulated with PUF insulation.

The non-air-conditioned part which comprised of Accounts, Cash, General section has been placed on south side to avail natural ventilation. As air-conditioned area will be on the north side of non-air-conditioned zone, outlet for cross ventilation will be provided in form of raised roof. This raised roof will be covered by insulated glass to allow natural light to the common spaces like corridors, staircase and waiting. As discussed earlier, to take advantage of trapped cooled air in the south-west portion of ground floor, cut outs have been kept in the first floor slab which will bring the cool air inside the non-air-conditioned areas due to stack effect caused by the solar chimney. Though the south side of the building will receive south breeze, it will be receiving the solar radiation for the whole day. To cut off direct sun, 500 wide vertical and horizontal sun shade have been provided for windows. These external members will be separated from the main wall by providing cut outs to reduce heat gains. To cut off direct sun light another horizontal member (light shelve), other than sun shade has been introduced dividing the window into two parts This light shelve will shade the window and upper part of it will reflect light to the ceiling to provide diffused day light. All the partition placed across the wind direction (south-north) will be designed as part brickwork/panelling and wooden louvers for easy air movements

For roof treatment, line terracing has been ruled out as future expansion will take place at a later day. Broken glazed tiles will be fixed over silicone based water repellent. The broken glazed tiles will reflect solar radiation and minimize heat gain The external finish of the building will be of ceramic tiles of light colour to minimize heat absorption

7.3 Special features of the proposed design

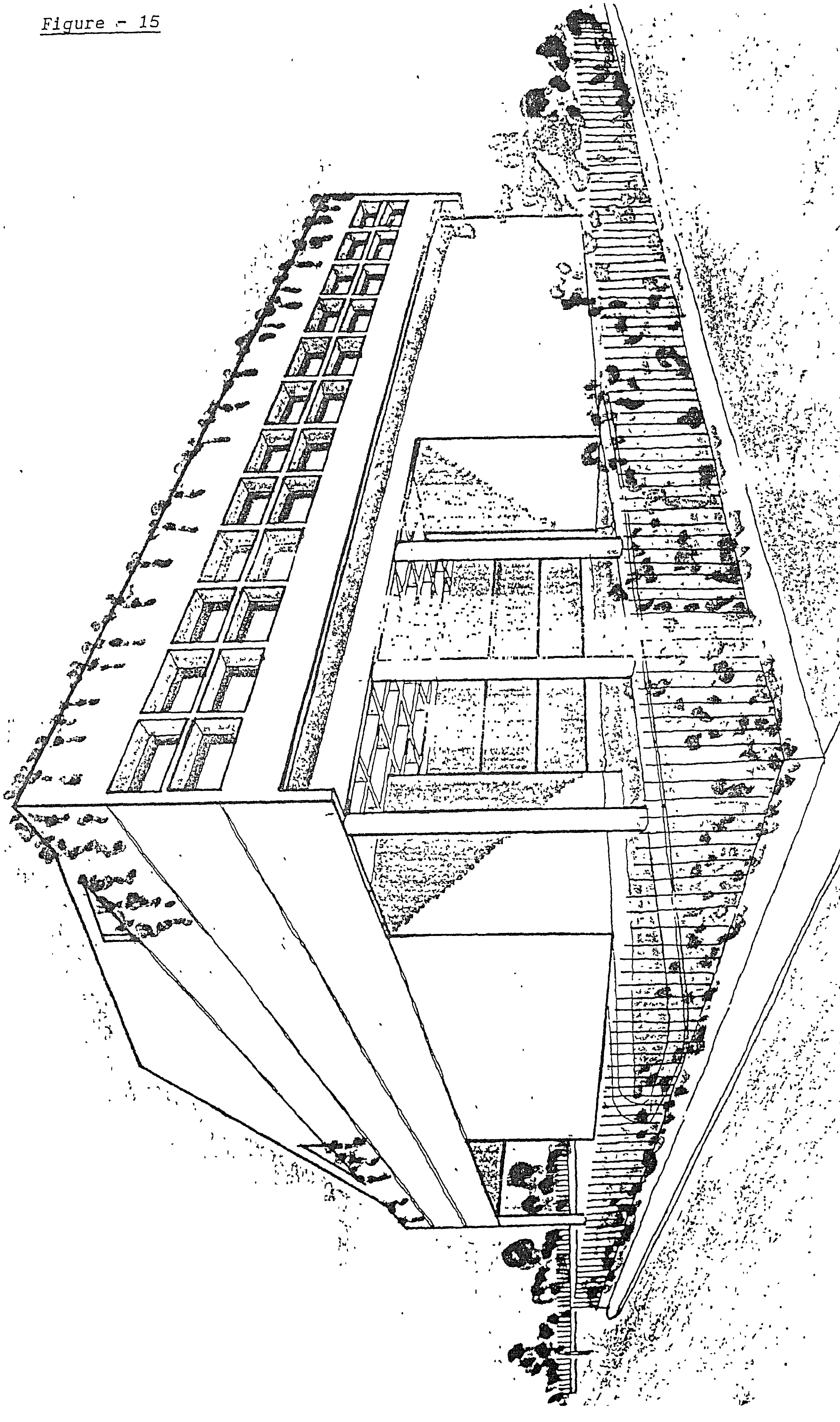
The special features which would make this building energy efficient are summarized below.

- Orienting the building E&W with little exposure to west sun.
- Providing high placed windows for admitting day light.
- No openings on west and east walls to reduce heat gain.
- A water body on south side of the building to modify air temperature.
- Providing floor cut outs and jalli walls to circulate cool south breeze from ground floor to upper floor and corridors.
- Providing high roof with louvered wall at top to flush out hot air with cool south breeze (good ventilation).
- Providing transparent glass cover on top of atriums and corridors with Low E Glass and large north windows to enhance the use of natural light.
- Using suitable colour and texture of false ceiling, flooring and paint which reflects sunlight, thus reducing power consumption for lighting.
- A few of the exposed elements in the outer envelope e g sidefins, overhangs, and light shelves, have been disjointed from main walls in order to stop the heat transmission towards the building interiors
- Use of solar PV system for lighting applications
- Insulation on east and west walls enclosing the air-conditioned areas.

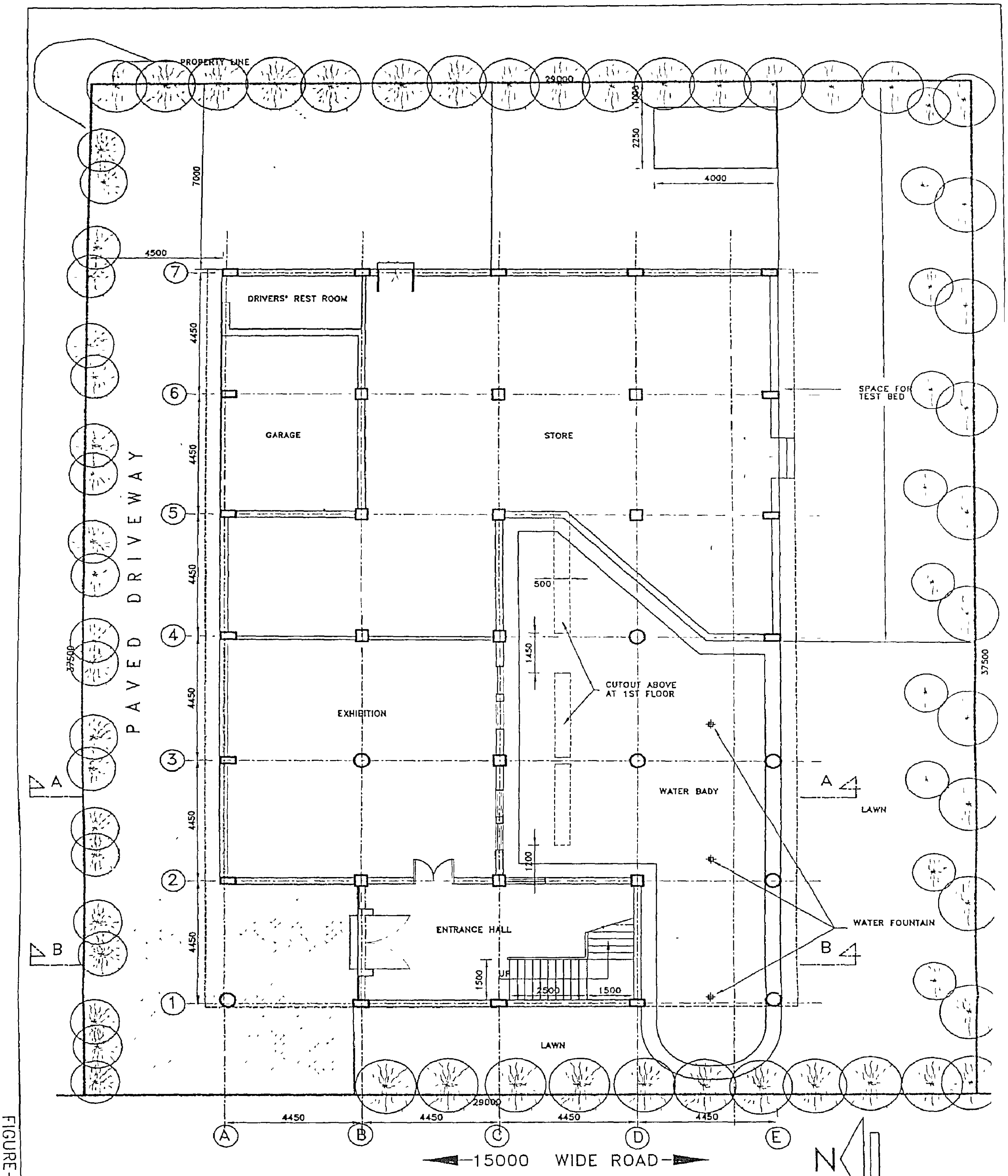
7.4 Materials

1. Insulated glass will be used for the windows of the air-conditioned areas and roof of the solar chimney.
2. Polyurethene foam (PUF) insulation will be provided on the east and west wall.
3. Broken glazed tiles will be fixed over silicone water repellent on roof.
4. False ceiling will be insulated with PUF.

Figure - 15



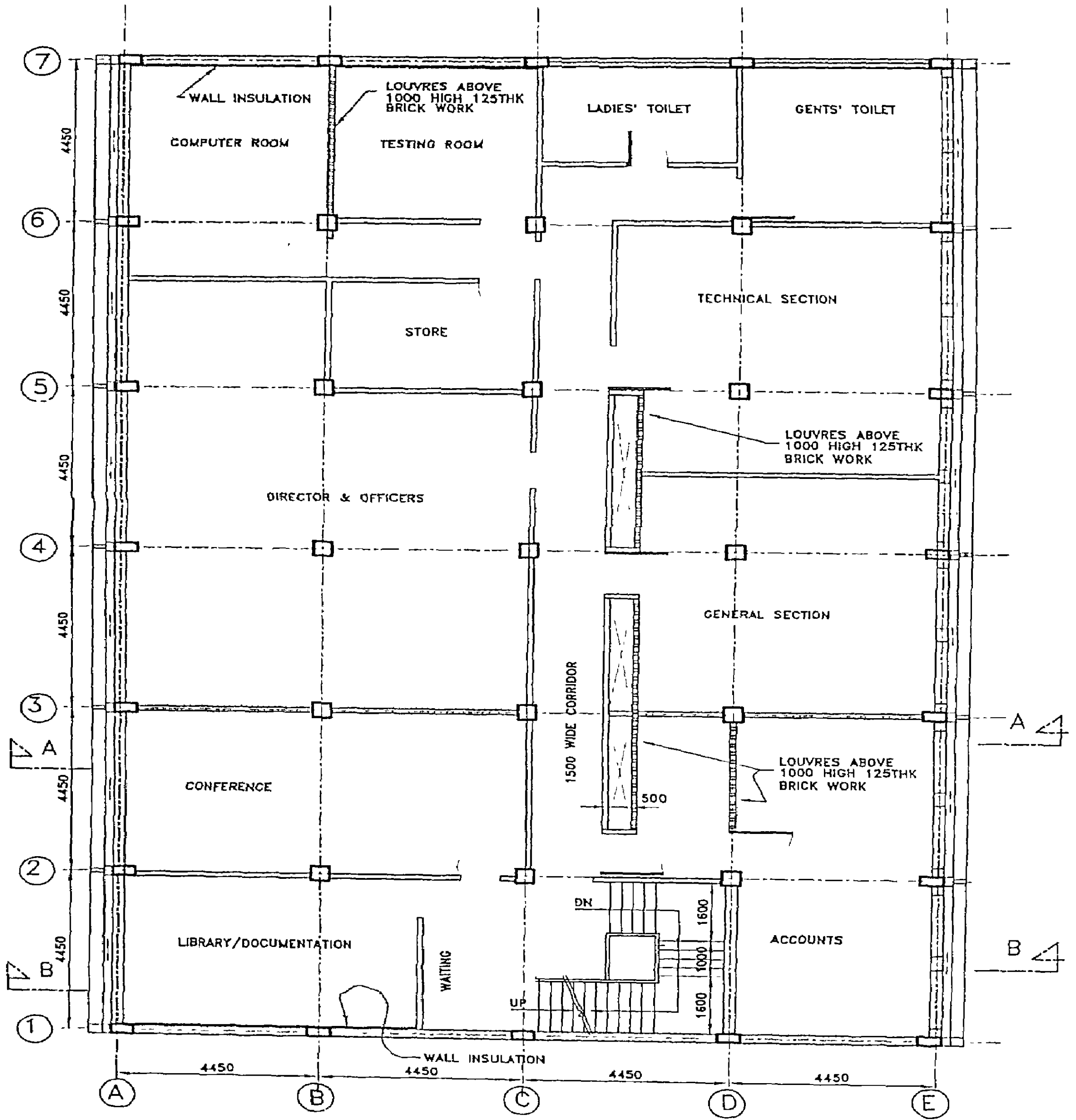
PROPOSED ADMINISTRATIVE CUM OFFICE BUILDING FOR WEST BENGAL RENEWABLE ENERGY DEVELOPMENT AGENCY



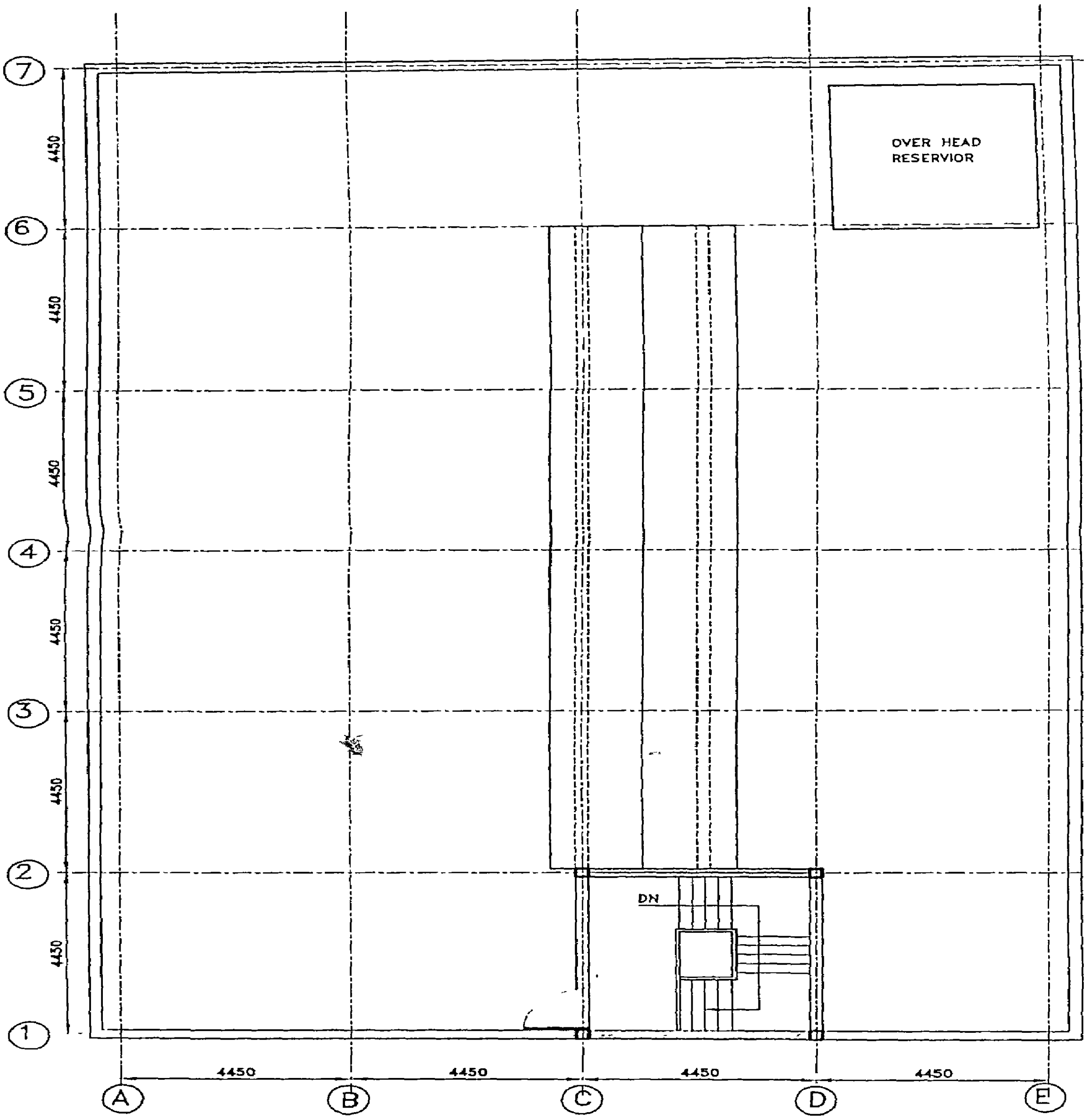
GROUND FLOOR PLAN

FIGURE-16

FIGURE-17

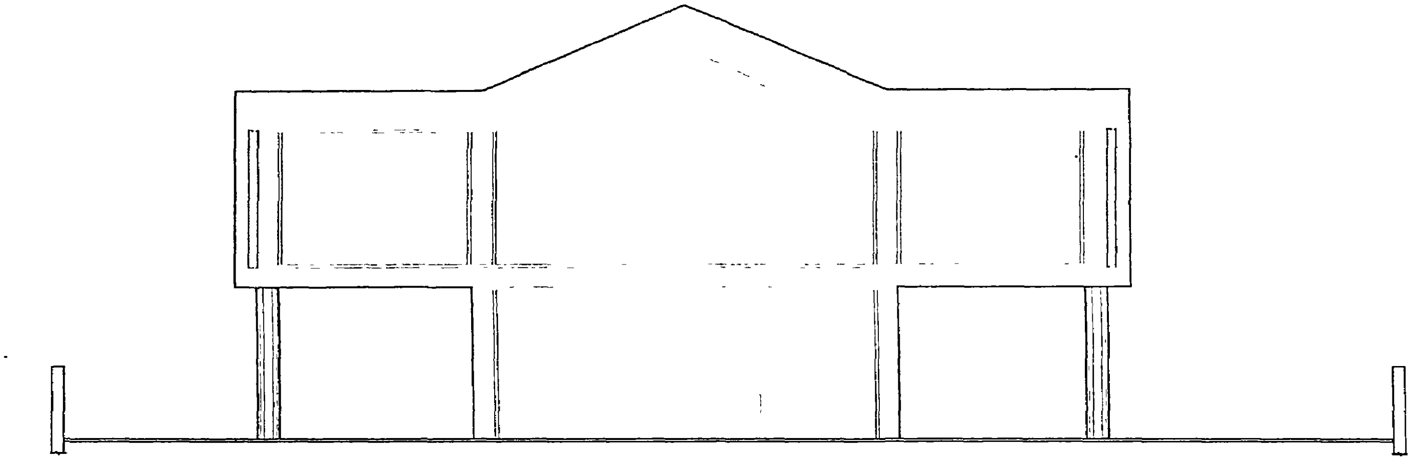


FIRST FLOOR PLAN

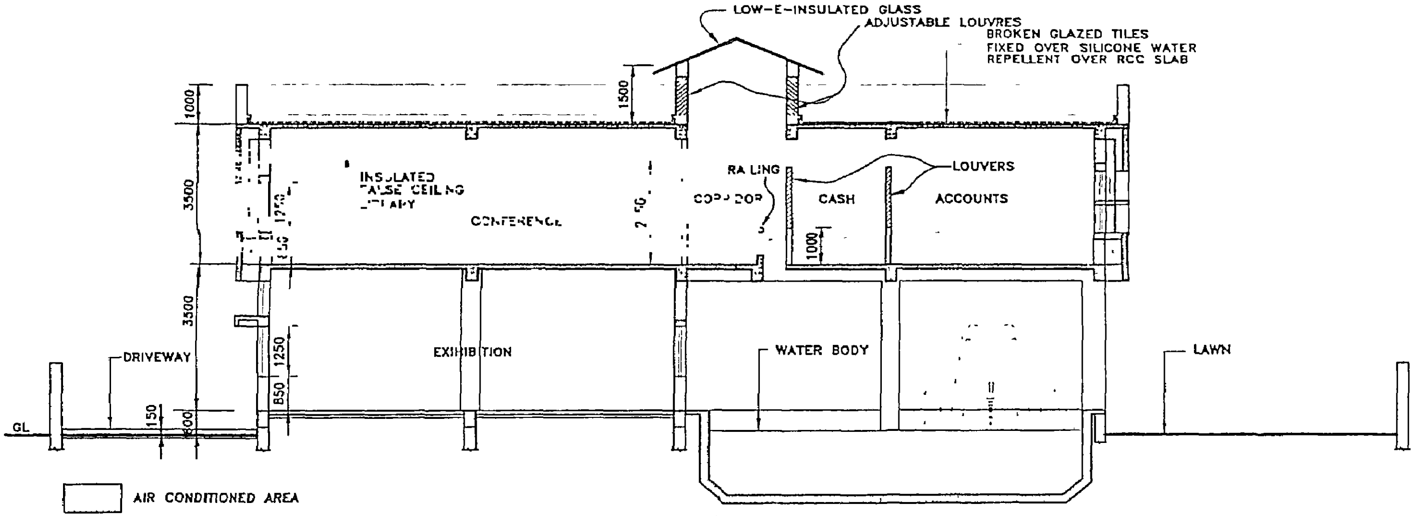


ROOF PLAN

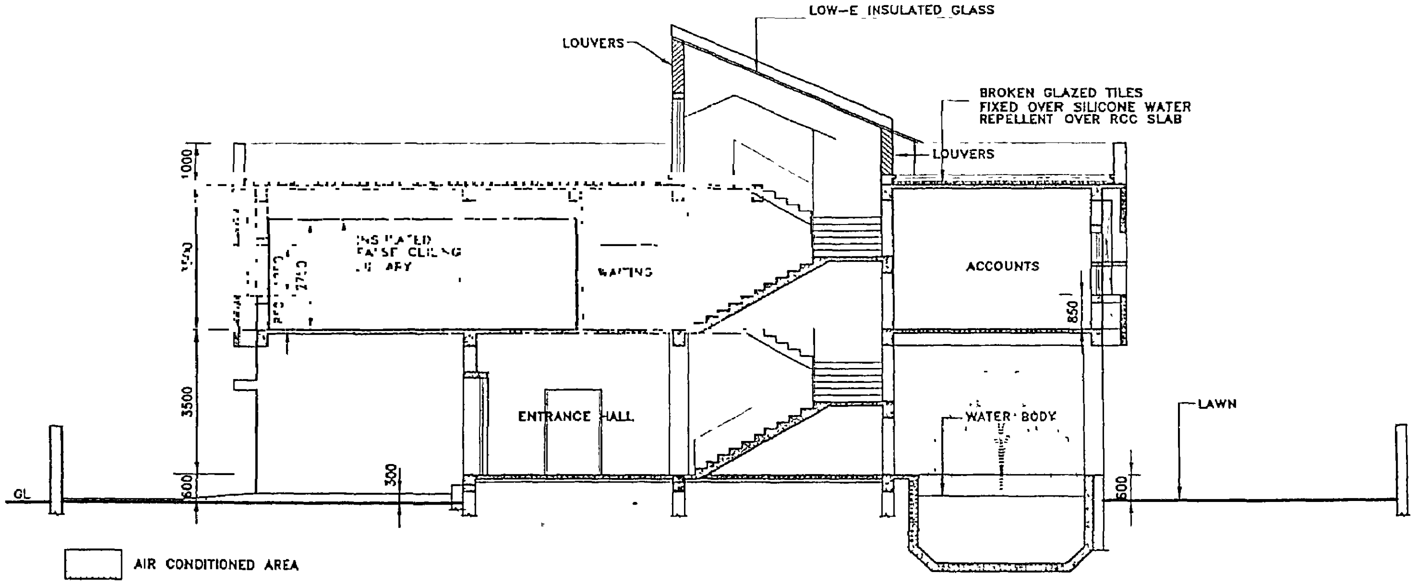
FIGURE-18



ELEVATION



SECTION—AA



SECTION—BB

8. Prediction of the thermal performance

The thermal performance of the proposed WBREDA office building has been analyzed using computer simulation techniques. The analysis of the building has been carried out for the entire year, but the focus of study has been a period of six months (April-September) when mechanical cooling is required to maintain thermal comfort inside the building. Major design strategies also try to reduce the energy that would be required for cooling. The assumptions made during the thermal analysis are as follows:

- Indoor and outdoor heat transfer coefficients are 8.0 and 23.0 W/(m^2-K) respectively.
- The air change rates considered in different areas are:
  - Air conditioned zone - 1 ACH (Air changes per hour)
  - Corridor and public areas - 5 ACH
  - Non-conditioned zones - 3 ACH

  It can be seen that conservative estimates according to normal practices for air change rates have been made. The values are based on the assumption that the good quality windows with proper sealing and weather-proofing would completely check infiltration.
- Heat loss coefficients for single and double glazed windows are taken to be 5.0 and 2.87 W/(m^2-K) respectively.
- The absorptivity of external finished surfaces is taken to be 0.4 (0.7 for grey surfaces)

Monthly energy aggregates (+ve: gain, -ve: loss) for the proposed building are shown in a bar chart (Figure 20), where the following quantities have been plotted as Bars for each of the six months (April-September):

- Solar gain - Total solar heat gain (shortwave) entering the building through the glazing.
- Window - Heat flow through all windows neglecting shortwave radiation effects)
- Ambient - Sum of all heat flows through walls and roof to the ambient.
- Ground - Heat flowing through floor to the ground node.
- Infiltration - Sum of heat flows due to infiltration and ventilation
- Int gain - Heat flow due to internal gains (equipments and occupants)

Both the internal gains (latent + sensible loads), and the solar gains constitute the major cooling load which is maximum for the month of May (Figure 22). Since the sum of nighttime heat losses through infiltration, glazing and opaque surfaces is more than the daytime gains, these quantities appear as losses in the figure.

A similar building (conventional office building) without the energy saving features was also analyzed to compare the performance of the proposed building and to estimate the net energy saved through conscious building design. The results of the analysis of the conventional building are given in Figure 21 where similar quantities (as in Figure 20) are plotted.

A comparison of the two figures shows that the proposed building would consume about 40% less energy for air-conditioning than the conventional building. In addition, the efficient lighting system to be designed for the building will consume about 60% less energy than in a conventional building. **Hence, the overall efficiency of the proposed building is about 50% more than the conventionally designed building, and at the same time, will provide better thermal and visual comfort.**

An air conditioner of capacity 14 TR would be required (against 21 TR for the conventionally designed building) to provide the cooling of the air conditioned areas Monthly cooling loads are given in Figure 22.

The heat flow through North Wall in the proposed building has been shown as line diagram (Figure 23) to show the effect of insulation in walls. It can be seen that on a typical hot day (11th May), the heat gain during the sunshine hours is reduced to about 20% of what would have transmitted through an un-insulated wall. The effect of insulation continues to reduce the gain at night time, it even converts to heat loss which is a favourable phenomenon in the hot and humid climate of Calcutta. Ambient temperature, solar temperature and solar radiation are also plotted in this figure for the convenience of the reader.

Figure 24 contains typical temperature profiles that are expected in the proposed office building. The indoor temperature in the non-conditioned zones reaches 32.5°C which is outside the range of comfortable temperatures (it would be 36°C in the conventional building), but it is expected that the enhanced ventilation aided by Solar Chimney and water bodies will further reduce the temperatures by 2-3°C - an affect which has not been considered during the thermal analysis of the building

The overall thermal performance of the building has been satisfactory and more detailed analysis of each building component would be done at a later stage while preparing the working architectural drawings. Finer details are being worked out to further increase the efficiency of the building.

Fig 20: Monthly Energy Balance
Proposed WBREDA office

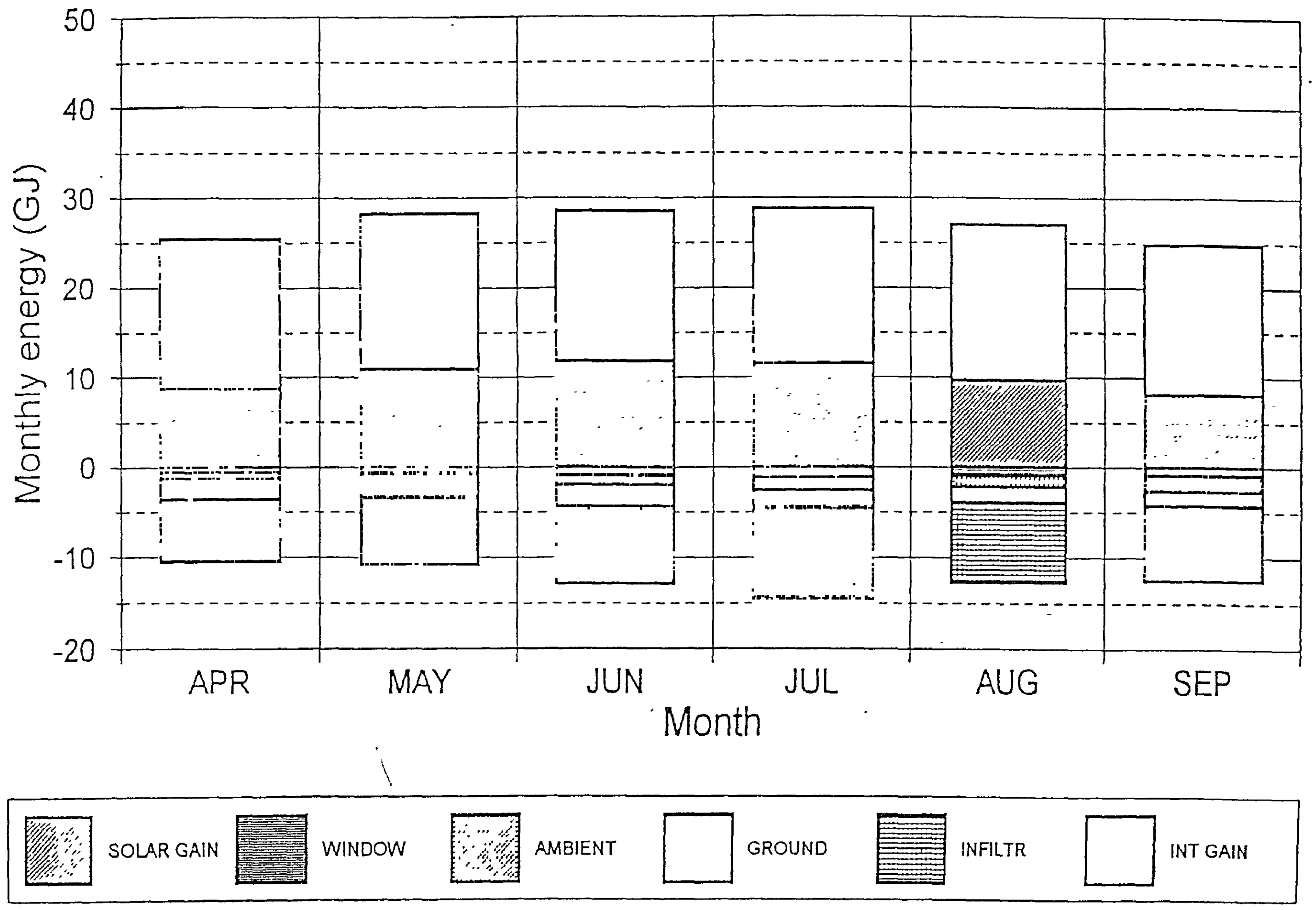


Fig 21: Monthly Energy Balance

WBREDA office (conventional design)

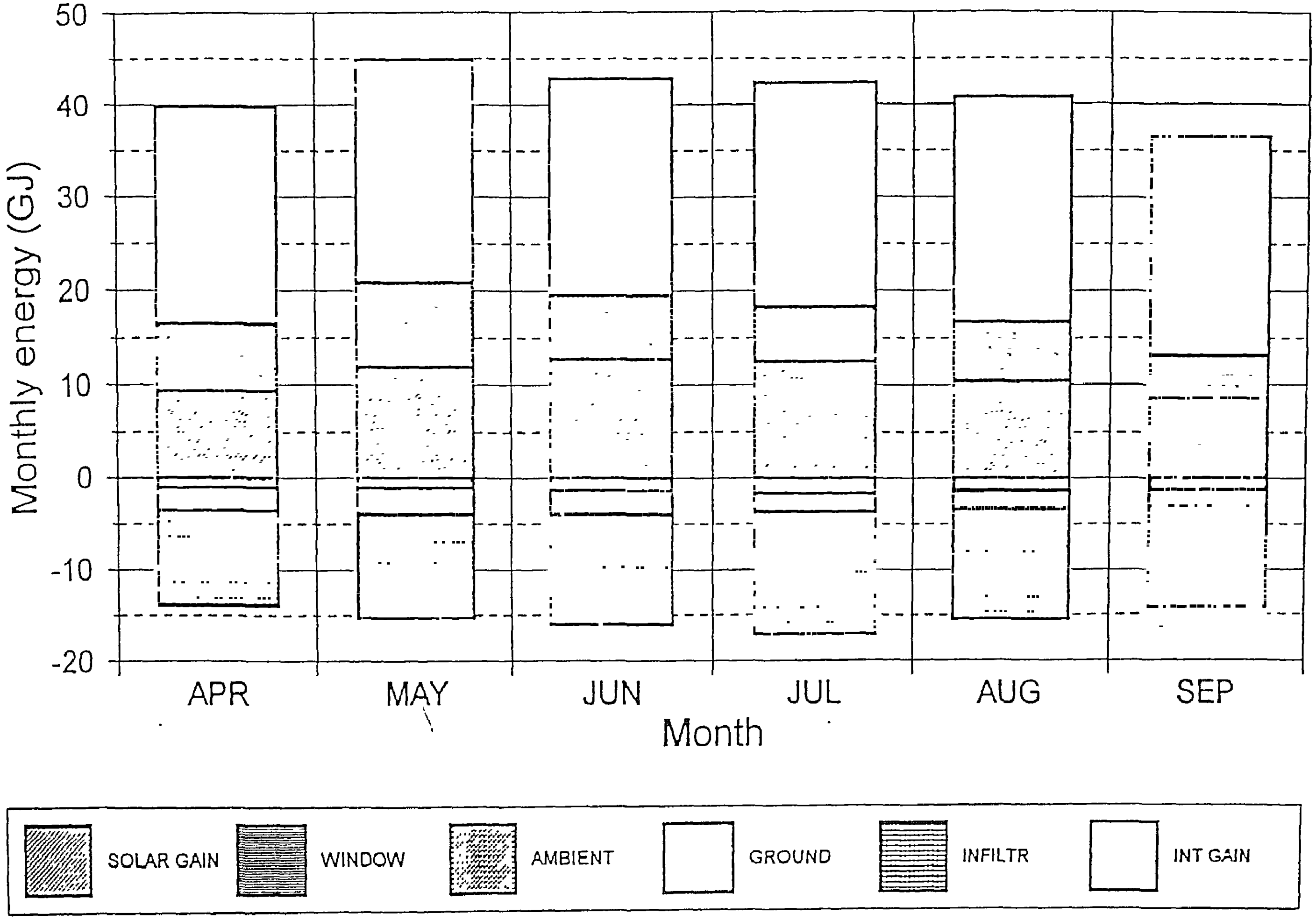


Fig 22: Monthly Cooling Loads

WBREDA office

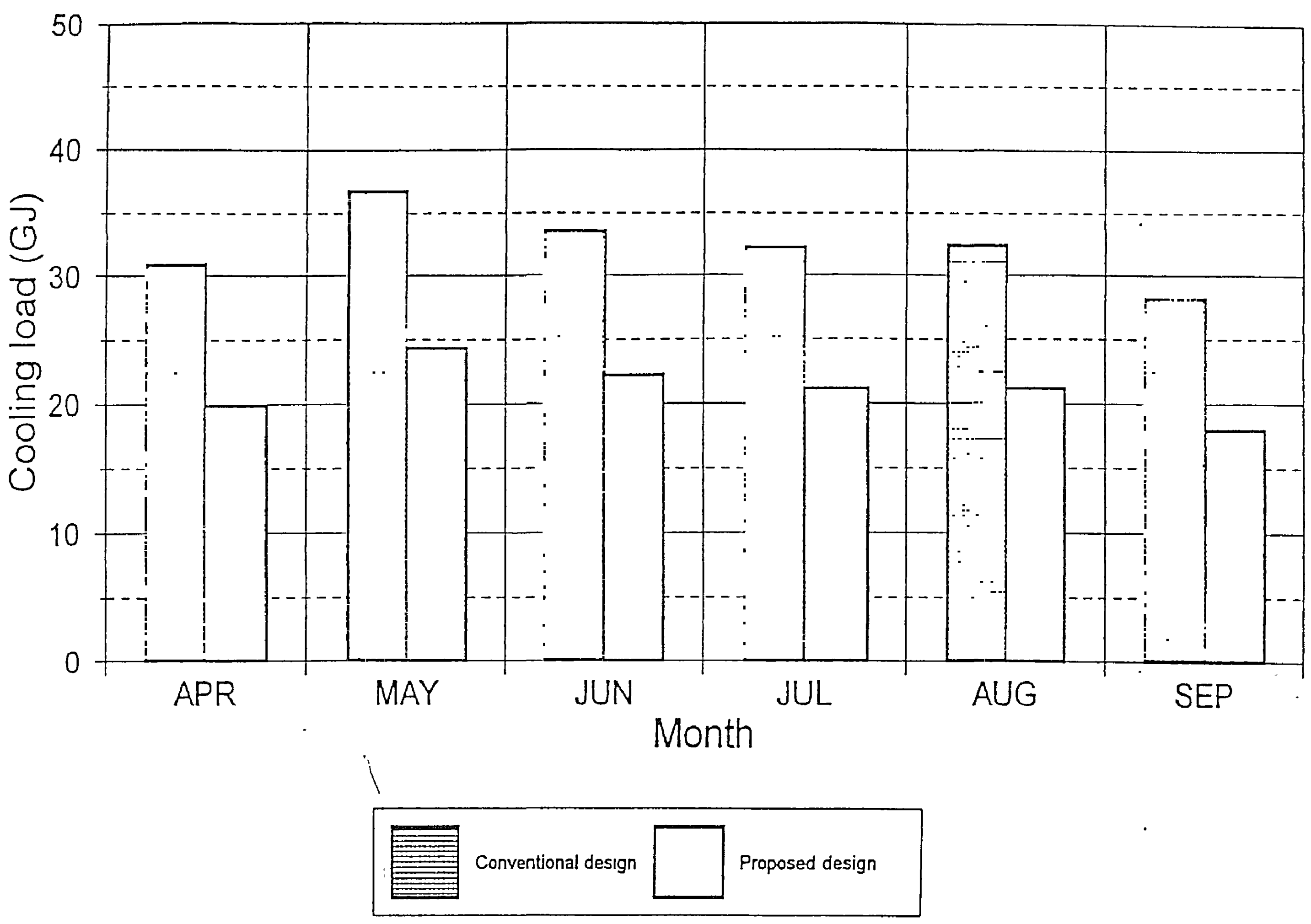


Fig 23: Heat Flow Through North Wall

WBREDA office

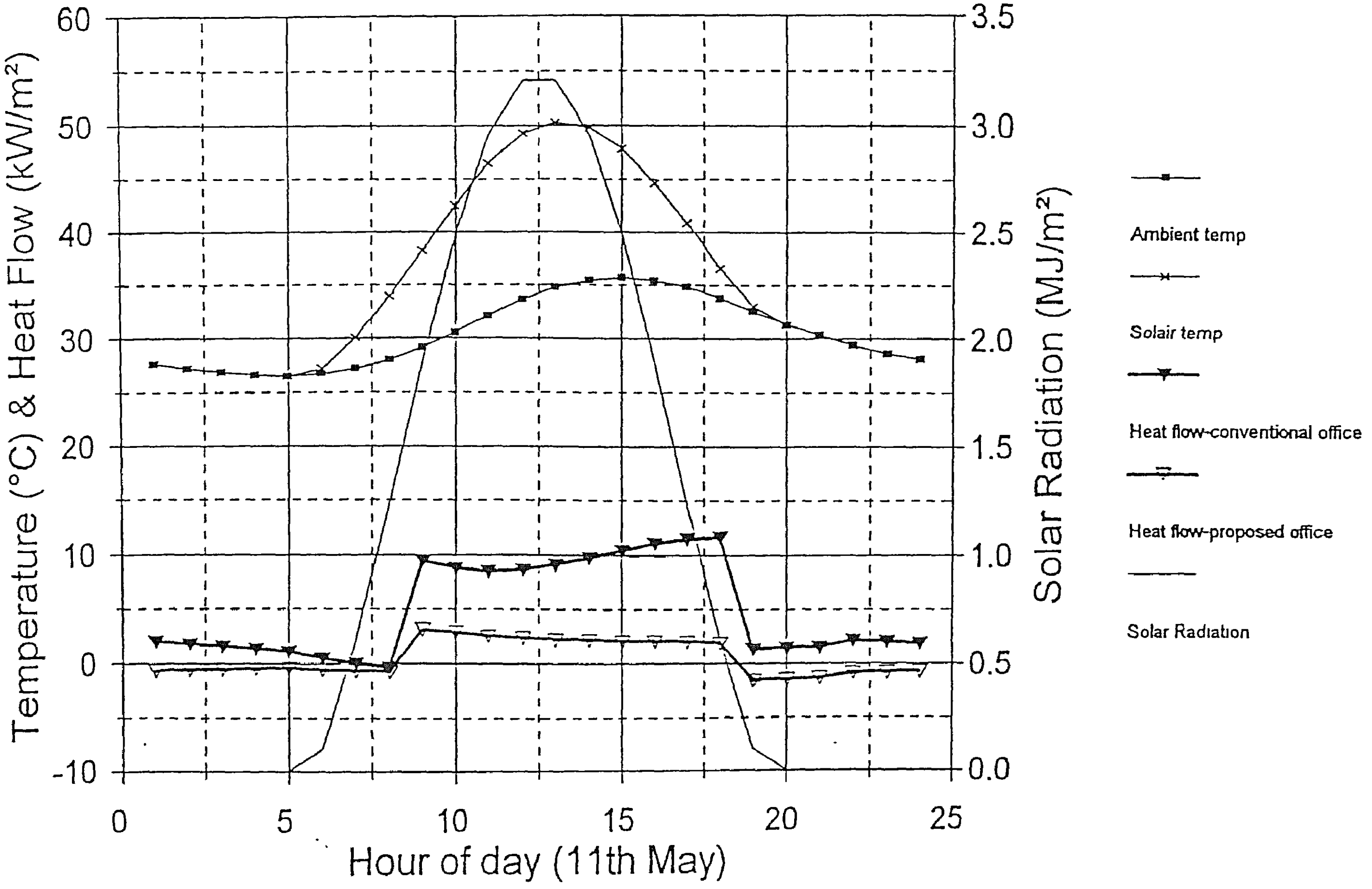
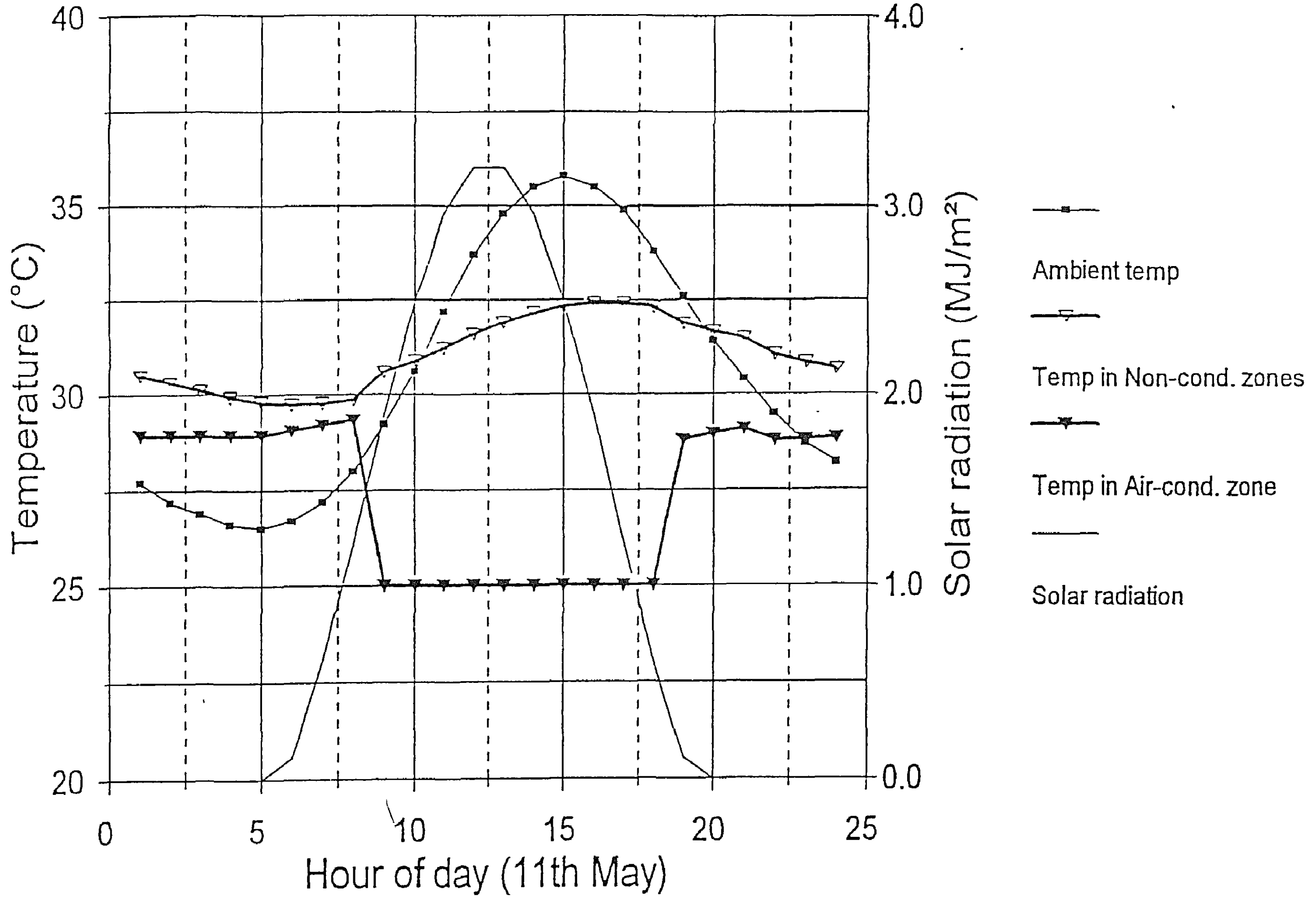


Fig 24: Typical Temperature Profile

Proposed WBREDA office



9. Cost Estimates

The cost estimates of the renewable energy systems and the entire project are mentioned in this chapter, which are only indicative.

9.1 Costs of the renewable energy systems

As mentioned earlier in section 6.6, only solar photo voltaic (PV) system has been proposed for lighting applications, in consultation with the officials of WBREDA. Besides necessity, it becomes a moral duty of WBREDA to demonstrate the renewable energy systems in its own building project because the agency is involved in the promotion of these systems.

The use of PV system would be for :

- providing energy light in the working areas in case of load shedding;
- illumination of all the public areas
- illumination of strategic areas (guard room, entrance etc), including drive way, and
- a small pump to run the fountain in the proposed pond on the south side of the building

The following would be supported by the PV system.

Item		Load
12 light points (compact fluorescent lamps, each of 13 W) in the ground floor		156 W
25 Light points (similar) in the first floor		325 W
3 light points at the Gate		39 W
One small motor/pump to operate the fountain		250 W
	TOTAL	770 W

Some of these light points will be used at night time.

A PV system of capacity 1 KWP, with an autonomy of 3 days has been proposed. In addition, three independant street light systems (12 hours use) with automatic switches are proposed to illuminate the drive way during night time.

Cost of PV system		Rs. 4.60 lakhs
Cost of Street light system (3)		Rs 0.90 lakhs
	TOTAL	Rs. 5.50 lakhs

9 2 **The costs of other items are tabulated below :**

Sl.No.	Elements	Amount (Rs. in lakhs)	Total
1.	Pile and Pilecap Work	15.00	
			15.00
2.	General Builders Work		
2.1	Earth work	0 20	
2.2	Ant-termite treatment	0.40	
2.3	Brick soling	0.45	
2.4	P.C.C.	1.00	
2.5	R.C.C.M - 20	18 00	
2.6	Brick work including 1/2 brick work	1.80	
2.7	Aluminium glazed door	0.50	
2.8	Wooden window with clear insulated glass	3.50	
2.9	Doors (Panelled and flush)	1.00	
2.10	M.S. Grill and rolling shutters	1.00	
2.11	Flooring (Mosaic, Kota, marble and PVC)	3.00	
2.12	Insulated false ceiling (Part)	0.50	
2.13	Wall insulation	0.60	
2 14	Painting work (Acrylic emulsion and synthetic enamel paint)	2.30	
2.15	Roofing (Silicon water repellent and white broken glazed tiles)	2.00	
2.16	Plastering	1.10	
2.17	Ceramic tiles to exterior face	5.00	
2.18	Miscellaneous work	0.10	42.45

Sl.No.	Elements	Amount (Rs. in lakhs)	Total
3.	External Work		
3.1	Water body	2.00	
3.2	Paved area (Part)	1.00	
3.3	Water reservoir (Reserve for fire fighting not considered here)	0.55	
3.4	Boundary wall	1 70	
3.5	Gardening	0.05	
3.6	Enabling work	0.10	
			5.40
4.	Sanitary Installation		
4.1	Internal and external work	1.50	
			1.50
5.	Electrical Installation		
5.1	Internal and external electrical work	3.00	
5.2	Contribution to WBSEB	0.30	
			3.30
6.	Fire fighting installation	0.50	
			0.50
	Total		68.15
	Add contingencies		1.85
	Total		70.00

10.0 References

1 Bansal, N.K. and Minke, G.
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2. ASHRAE Handbook of Fundamentals 1985.